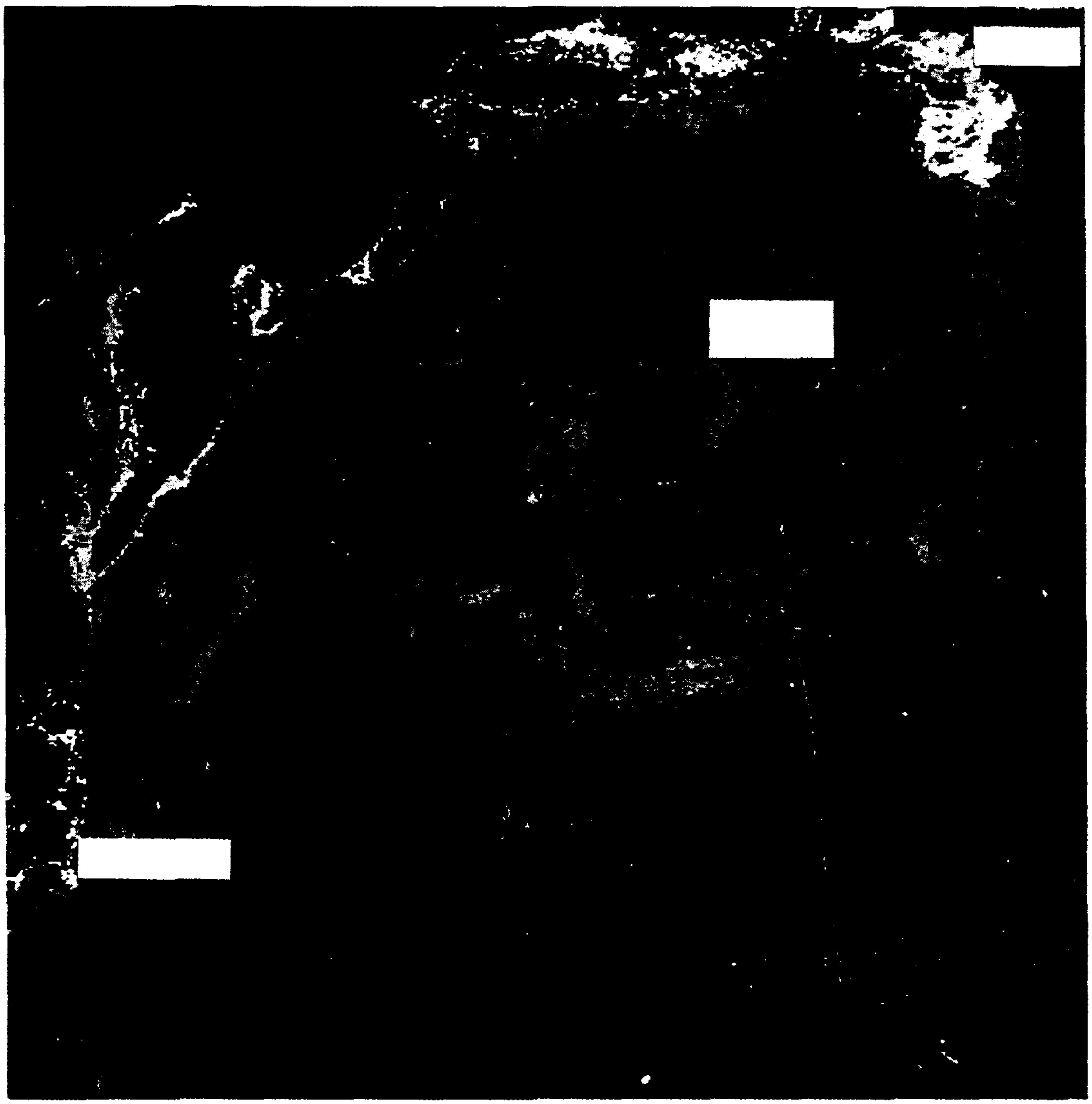
NOAA Estuarine and Coastal Ocean Science Framework



October 1987

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NOAA Estuarine Programs Office

NOAA Estuarine and Coastal Ocean Science Framework

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U.S. DEPARTMENT OF COMMERCE
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COVER PHOTOGRAPH: The satellite image from the Nimbus 7 Coastal Zone Color Scanner depicts phytoplankton distribution along the U.S. east coast. Higher concentrations are shown in reds and yellows, lower in blues and greens. This image illustrates the high productivity and importance of this estuarine and coastal ocean system.

NOAA ESTUARINE AND COASTAL OCEAN SCIENCE FRAMEWORK

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FOREWORD

The NOAA Estuarine and Coastal Ocean Science Framework provides long-term scientific direction in four critical estuarine and coastal ocean problem areas: freshwater inflow and circulation alterations; toxics, nutrients, and pathogens; habitat degradation; and declines in living resources. The scientific agenda described in the Framework is the foundation for NOAA's long-range planning to address these problems. Details for implementing the Framework will be developed in a series of Program Plans that will determine NOAA's short-term priorities in the context of the Framework. These Program Plans will be reviewed annually and together with the Framework, will guide NOAA's estuarine activities into the next century.

NOAA ESTUARINE AND COASTAL OCEAN POLICY

Estuaries and their associated coastal waters are the site of critical ecological processes that are the basis of the ocean's biological productivity. Adding to their ecological value, much of the Nation's economic growth and development is dependent on these coastal waters. At the same time, the fertile estuarine environment is highly susceptible to a variety of adverse natural and human-related factors. The National Oceanic and Atmospheric Administration (NOAA) considers the improved health and productivity of these coastal waters to be of the highest priority. To enhance Federal and state capabilities to manage this critical environment, NOAA has developed a long-term scientific strategy to support the wise use and management of estuarine and coastal resources. This strategy, NOAA's Estuarine and Coastal Ocean Science Framework, addresses critical estuarine and coastal ocean issues in time scales relevant to public policy decision-making.

NOAA's goal in estuarine and coastal ocean science is <u>to understand and predict natural ecosystem processes to provide the capability to assess the effects of human activities on estuarine and coastal ocean resources</u>. NOAA will achieve this goal by directing the Agency's multi-disciplinary resources and capabilities on the objectives described in the following problem areas:

<u>Freshwater Inflow and Circulation</u>

> To improve our capability to predict the effects of hydrological forcing on estuarine and coastal ecosystem functioning through increased understanding of circulation and changes in freshwater inflow.

<u>Toxics, Nutrients, and Pathogens</u>

> To define the extent of environmental degradation caused by contaminants in the estuarine and coastal ocean environment and to determine the effects of contaminants on living resources.

<u>Habitat</u>

> To understand the importance of habitat and to predict the effects of habitat loss or physical alteration on populations of living resources.

<u>Living Resources</u>

> To understand the causes of living resource declines and to predict the effects of human activities on populations of important species.

EXECUTIVE SUMMARY

Introduction

Our Nation's estuaries and their associated coastal waters are vital, productive natural systems. They also support a great number of commercial, recreational, residential, and industrial activities. Demographic trends indicate that by 1990 approximately 75 percent of the Nation's population will live in the coastal states. Accompanying this coastal population growth will be increasing pressures on and competing uses of the coastal and estuarine environment and its resources. There is a clear need for effective and timely scientific information to support a balanced approach to the development of our estuarine and coastal areas. The National Oceanic and Atmospheric Administration (NOAA) is uniquely qualified to respond to this challenge. NOAA's legislative responsibilities and capabilities in resource conservation, atmospheric science, ocean system dynamics, biological processes, and coastal ecosystems management provide a solid foundation for addressing these issues through an inter-disciplinary approach.

This Estuarine and Coastal Ocean Science Framework provides long-term guidance for addressing the priority resource management issues of our estuaries and coastal oceans. NOAA's goal in this effort is to understand and predict natural ecosystem processes to provide the capability to assess the effects of human activities on estuarine and coastal ocean resources. The four areas of concern addressed in the Framework are: 1) alterations in freshwater inflow and circulation; 2) toxics, nutrients, and pathogens; 3) habitat loss and degradation; and 4) declines in living resources. Each of these categories comprise separate chapters of the Framework, as described below. Strategies to address the problem areas are examined according to NOAA's functions of observation/assessment, research, and synthesis/prediction. A series of specific questions delineates the information needed to carry out each strategy.

Freshwater Inflow and Circulation

Estuarine and coastal ocean waters are influenced by a complex set of hydrological forces including freshwater inflow and circulation patterns. Changes to these forces can have dramatic consequences on the distribution and effects of contaminants in the system. In addition, alterations of freshwater inflow, such as by diverting or damming the rivers that normally flow into estuaries, can affect the salinity and thus the productivity of estuarine and coastal systems. Advances in our basic knowledge of how freshwater inflow and circulation patterns influence the transport of contaminants and biological productivity will greatly enhance our ability to manage these valuable ecosystems.

Toxics, Nutrients, and Pathogens

Human activities and waste products introduce many contaminants to estuaries and coastal systems, including toxic chemicals, nutrients, and pathogens. Although a number of studies demonstrate that many of our estuaries and coastal waters are "contaminated," these studies have not fully determined the sources, extent, and magnitude of contamination or its effects. Research and assessments are needed to identify the sources and magnitude of contaminants and how these materials are transported and altered after they enter the environment. Research efforts should also be initiated to determine the effects of contaminants on individual organisms, populations, and communities of organisms. With improved knowledge, we will significantly increase our capability to predict the effectiveness of contaminant control measures and enhance our ability to conserve estuarine and coastal resources.

Habitat

Many estuarine and coastal areas that provide critical habitat for many important fisheries are being degraded and are rapidly disappearing. Human activities and natural causes have resulted in the loss of half of our Nation's coastal wetlands since 1780; the rate of loss is now estimated at 60 square miles per year in areas of Louisiana. Our ability to assess the immediate and long-term effects of human activities on estuarine resources depends on an increased understanding of habitat functions, the quantity of habitat loss, and the rate of recovery of damaged systems. Our ability to mitigate habitat loss through existing regulatory programs also depends on new information. An improved understanding of habitat functioning is critical for the effective management of our estuarine-dependent fisheries.

Living Resources

Estuaries and coastal regions are among the most biologically productive ecosystems in the world, providing critical habitats for many of our important fisheries. However, dramatic declines in several of these fisheries have occurred, because of habitat loss or pollution, overfishing, environmental alterations, disease, and natural variability of the stocks. Effective fisheries management requires an improved understanding of these factors and of key trophic relationships in the ecosystem.

Improved knowledge of these ecological processes must then be combined with current information on the health, distribution, and abundances of important organisms. Predictive models can then be developed to evaluate alternative fishery and habitat management strategies.

Framework Implementation

The NOAA Estuarine and Coastal Ocean Science Framework is the Agency's long-range strategy for coordinated and concerted action to address the deterioration of the Nation's estuarine and coastal resources. Through directed scientific investigation, NOAA will improve our understanding of ecosystem functioning and our prediction of the impact of alterations on estuarine ecosystems. This, in turn, will provide the Nation's estuarine and coastal resource managers with a stronger scientific basis for management and regulatory decisions.

To implement the Framework, NOAA will concentrate the Agency's multi-disciplinary resources and capabilities on the problem areas described herein. Primarily, this will be accomplished through detailed annual Program Plans, which will identify Agency strategies to address priority issues over the short-term, specifying proposed program directions and funding levels. NOAA will also use its oversight and consultative responsibilities with state and regional management plans to emphasize Framework priorities. For instance, in NOAA's evaluations of state coastal zone management programs, the Agency will encourage alignment of the states' coastal management goals and standards more closely with the Framework's objectives in areas such as wetlands mitigation, water management, sedimentation control programs, fisheries and habitat data collection, and non-point source controls.

It is also crucial that NOAA ensure close integration of its management and technical activities in estuarine programs. For this purpose, NOAA will rely on its existing programs and facilities, including laboratories, ships, Estuarine Research Reserves, Sea Grant Colleges, and coastal zone management liaisons with the states. These facilities have the potential to provide an extensive network of estuarine and coastal ocean expertise. NOAA will strengthen this network and existing information dissemination activities, to improve the transfer of information to managers of estuarine and coastal resources. NOAA will also work to improve coordination and communication with other Federal agencies that have responsibilities affecting the estuarine and coastal ocean environment. The Framework recommends an ad-hoc interagency committee of such agencies, to identify strategies for coordinating major Federal program initiatives.

Chapter I

INTRODUCTION

CHAPTER I

INTRODUCTION: THE ESTUARINE AND COASTAL OCEAN SYSTEMS

I. A NATIONAL CONCERN

While estuaries[1] and their associated coastal waters comprise less than one percent of the ocean environment, they are the most valuable component of the world's oceans (see Figure 1). These fertile environments represent the biological foundation of the entire marine ecosystem. Enriched by nutrients from the land, mixed by tides and currents, and saturated by sunlight, estuaries feed, support, and shelter a rich and varied ecological system -- and as a result provide a remarkable level of biological productivity. Salt marshes, for example, yield ten tons of organic material per acre per year, compared to only four tons per year produced by fertile hay fields.

Estuaries provide the food, shelter, and spawning grounds for over 70 percent of our commercial fisheries by weight, worth $5.5 billion to the GNP in 1986. Seven of the ten most valuable commercial fisheries -- Gulf shrimp, sockeye salmon, menhaden, pink salmon, oyster, South Atlantic shrimp, and blue crab -- depend on the estuaries to survive. The estuarine and coastal ocean systems are also critical in sustaining recreational fishing, an industry that generates expenditures of over $7.5 billion annually.

Not only are these environments extremely valuable in terms of productivity, but for centuries society has also placed enormous value on coastal areas for living, working, and recreation. Today, over 70 percent of our population lives in coastal states (including those bordering the Great Lakes), and it is predicted that by 1990 this figure will rise to approximately 75 percent. Much of the growth in population is expected to occur along the Gulf and Southeast coasts, where development has not yet severely degraded many important estuarine and coastal ecosystems (see Figure 2).

Clearly, this growth has not come without a price. Dramatic increases in population and accompanying land-use changes, as shown for the Chesapeake Bay in Figure 3, correspond with major changes in water and sediment quality and significant declines

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1 For the purpose of this Framework, the estuarine and coastal ocean complex includes not only the traditionally defined estuarine system, but also the coastal waters where saltwater and freshwater mix, as well as the waters of the Great Lakes.

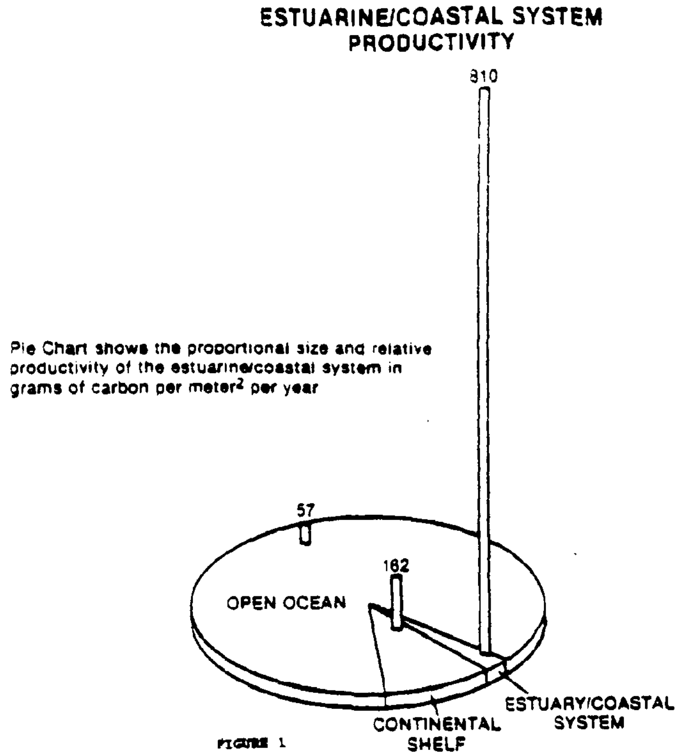


FIGURE 1

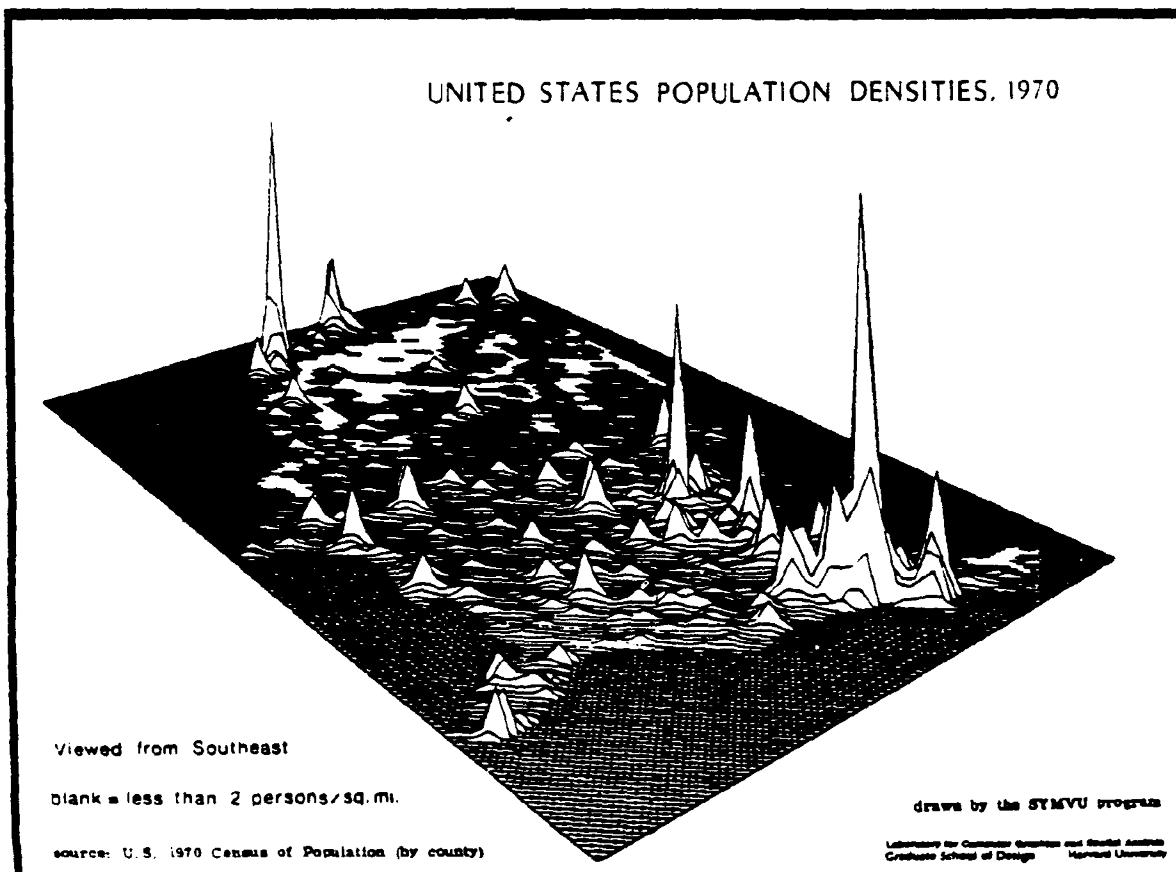
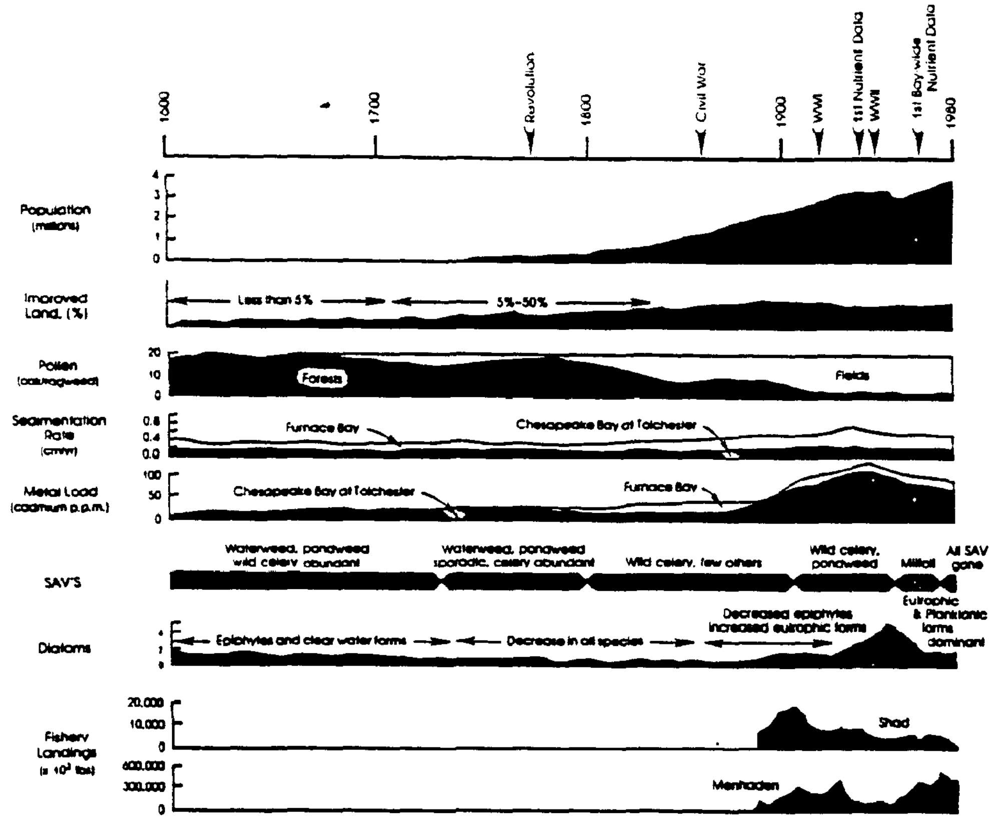


FIGURE 2



TIME HISTORY OF NORTHERN CHESAPEAKE BAY, 1600 TO 1980. An important aspect of understanding how Chesapeake Bay will respond to pollution is to examine the Bay's past. In the northern Bay, human activity, beginning at the top of the chart with population growth has been changing water quality since the time line began.

(Source: US Environmental Protection Agency, 1983)

FIGURE 3

in submerged aquatic vegetation and estuarine-dependent fisheries. Accompanying the coastal population increase is competition for estuarine and coastal resources. Competing uses such as water diversions, waste discharges, and habitat alterations have profoundly affected the integrity of our estuarine and coastal ecosystems and ultimately may jeopardize their economic value -- often in the form of long-term environmental degradation, fisheries loss, property value declines, and threats to public health and safety.

Many of the rivers that normally flow into the estuaries have been diverted, leveed, or dammed, to meet our agricultural, energy, and flood control needs. These modifications and diversions alter the freshwater inflow to estuaries, resulting in fundamental changes to the ecosystem. Obstructions on these rivers also prevent many of our most valuable anadromous fish from returning upstream to spawn, and often irreversibly alter their habitat. For example, large scale construction of hydroelectric dams in the Columbia River, combined with intensive logging practices, has led to severe declines in the Northwest salmon fishery.

The use of coastal waters for waste disposal has also caused significant degradation of estuarine and coastal resources. New York City and Los Angeles release 1.5 billion and 900 million gallons of sewage effluent per day, respectively. Boston discharges 500 million gallons per day, along with a half million gallons of raw sludge per year. These discharges include thousands of tons of nutrients that disrupt inshore ecosystems, resulting in shellfish closures and fish kills. Sewage discharges have led to closure of one-third of the 4000 acres of clam flats in the vicinity of Boston Harbor, while nutrient-induced oxygen depletion triggered massive fish kills off the New Jersey coast in 1976, precipitating a $60,000,000 loss to the commercial clam fishery alone. Sewage disposal has also affected the shrimp industry in Pensacola/Escambia Bay, Florida, where catches declined from 902,000 pounds in 1968 to 17,000 pounds in 1971.

Industrial waste discharges, often containing highly toxic material, may be even more threatening. The effects of industrial pollution have been strongly felt in New Bedford Harbor, Massachusetts -- a major center of the U.S. fishing industry. Lobsters are a lucrative component of the New Bedford catch, yet they are no longer taken from the Harbor's resident populations. Years of dumping wastes from neighboring electrical industries has raised the level of polychlorinated biphenyls (PCBs) in the harbor sediments to over 200 parts per million. NOAA has estimated that the total loss to commercial lobstermen is $2,100,000, and to recreational fishermen, $1,900,000. Revenues lost to date from beach closures are estimated to be $14,700,000, while declines in residential property values have exceeded $30,000,000.

Wetlands loss is another significant factor affecting the vitality of estuarine and coastal resources. Research has established that over 120,000 juvenile shrimp per acre are sustained by Louisiana's shallow marsh regions. However, some areas of coastal Louisiana are losing an estimated 60 square miles of coastal wetlands per year. This loss may have a significant effect on the size of Gulf shrimp harvests. In San Francisco Bay, diking and filling have reduced the original 300 square miles of wetlands to less than 75 square miles. Corresponding to these wetland losses has been a decline of fish and shellfish harvests. In fact, the salmon population in the Sacramento River has decreased by over 50 percent.

The evidence clearly indicates that the health of our estuaries is declining. It is time to re-examine what should be done to conserve one of the Nation's most valuable resources. Unfortunately, the effects of human activities and natural changes to our estuarine and coastal environment are not well understood. We cannot reliably predict the fate and transport of effluent from sewage treatment plants in Boston Harbor or Chesapeake Bay, determine what organisms are exposed to its toxics, or anticipate where nutrient-induced anoxia will lead to more fish kills. We have yet to discern how PCBs are transported from New Bedford Harbor, Raritan Bay, or Elliott Bay to other areas through the food chain. We know that Gulf shrimp require wetland habitat for survival, but we do not know precisely how many shrimp are lost with the loss of each acre of wetland. NOAA has developed this Estuarine and Coastal Ocean Science Framework to focus NOAA's resources and capabilities on the important problem areas outlined in subsequent chapters. The remainder of this chapter presents a synopsis of Federal agency responsibilities in the estuarine and coastal ocean system, NOAA's authorities to conduct estuarine activities, and an overview of current NOAA programs that address Framework priorities.

II. FEDERAL ROLES AND RESPONSIBILITIES

Governmental responsibilities to address the problem of the deterioration of our Nation's estuarine and coastal resources are derived from common law, public trust obligations, Constitutional law, and specific statutory mandates. Because estuaries and coastal waters involve common property resources that cross geo-political boundaries, the Federal Government and the individual states share jurisdiction and responsibility for the wise use and management of the resources in this area.

Federal legislation affecting water quality, coastal zone management, and fisheries management and conservation has sought to provide incentives for increased state involvement in the day-to-day management of estuarine/coastal resources. Federal initiatives responding to these laws have been directed toward strengthening state and regional resource management capabilities and making the results of Federal research and information activities available to guide management decisions. By establishing a National Estuary Program under the Water Quality Act of 1987, Congress reinforced the existing Federal role that was established in the Coastal Zone Management Act of 1972 -- that of providing scientific and management support in response to state management needs and national concerns. As a result of these and other historical Federal mandates, a number of distinct estuarine and coastal related programs have evolved in several agencies. An overview of NOAA's programs is included in Section III of this Chapter and a detailed legislative analysis is provided in Appendix A. A summary of the other Federal programs is provided below and Appendix B describes them in greater detail.

Environmental Protection Agency (EPA)

Within the Federal Government, EPA has the lead for controlling environmental pollutants. EPA's mission is to reduce the public's exposure to harmful pollutants, protect sensitive ecosystems, and improve management of environmental regulatory programs. EPA develops standards and criteria for the states to use in regulating point source discharges of pollutants. These sources include sewage treatment plants, power plants, refineries, and petrochemical producers and other industries. EPA has taken the lead in coordinating studies and assisting states with developing basin management plans for the Great Lakes, Chesapeake Bay, as well as six other estuaries through the National Estuary Program. The Water Quality Act of 1987 now provides EPA with new estuarine-related authorities. In particular, EPA is responsible for establishing management conferences for estuaries of national significance. Through these conferences, research and management programs will be integrated to protect and improve water quality, enhance living resources, and provide a mechanism to enable conflicting uses to be balanced so that the environmental integrity of the estuary is maintained. The Water Quality Act also authorizes EPA to administer a program requiring states to develop non-point source action plans for reducing non-point source pollutants in surface water. EPA has also begun implementing its Near Coastal Waters Initiative, a long-term planning strategy designed to improve EPA's ability to manage the environmental quality of near coastal water ecosystems.

Soil Conservation Service (SCS)

The SCS mission covers three major areas: soil and water conservation, natural resource surveys, and community resource protection and development. Through its nationwide network of conservation specialists, the SCS provides technical assistance to farmers, ranchers, and foresters on methods to control erosion and sedimentation through best management practices, and to control non-point sources of water pollution. The SCS maintains extensive data archives on wind and water erosion, land-use and cover, conservation practices, and treatment needs. To assist land owners in protecting natural resources, the SCS also administers cost sharing programs that offer special assistance for installing certain conservation practices, protecting wetlands, and improving water quality.

U.S. Army Corps of Engineers (Corps)

The Corps is vested with the authority to maintain navigable waterways and to issue permits for the transportation of dredged material for ocean dumping and for the discharge of dredged or fill material into the waters of the United States. As the Federal organization that administers the dredge and fill permit programs in the Nation's estuaries and coastal waters, the Corps programs are critical to the maintenance of estuarine system productivity. The Corps receives over 10,000 permit applications annually. The Corps estuarine-related research is, therefore, primarily related to identifying solutions for dredged material disposal. Some of these efforts include determining the bio-magnification and bio-accumulation of contaminants in the estuarine environment, and developing guidelines for disposal of highly contaminated sediments.

U.S. Fish and Wildlife Service (FWS)

The FWS has general responsibility for maintaining the fish and wildlife resources in the United States and providing public access to these resources. Its functions include responsibility for fish and wildlife resources and habitats of national interest through research, management, and technical assistance to other Federal and non-governmental agencies.

The operations of the FWS include those conducted in the coastal zone, the contiguous lands, and the waters that flow into the zone. Major FWS programs involving coastal issues include permit review and resource planning; land acquisition and habitat management (through refuges and easements); management of migratory birds, anadromous fish and endangered species; and a broad research activity addressing causes and effects of habitat change and coastal contaminants. These programs provide for the collection, synthesis, and interpretation of diverse information on species, populations, and habitats that is assembled, analyzed, and applied for management purposes.

U.S. Geological Survey (USGS)

The USGS performs hydrological investigations in streams and subsurface waters. Some of this work is conducted in estuaries or at the fall lines of river systems. The USGS operates downstream gauges on major rivers and streams, and conducts site-specific investigations of estuarine circulation, geochemistry, and ecology. Much of this work is conducted in the Potomac River, where hydrodynamic and geochemical processes, as well as long-term changes in wetlands ecology are being studied. In San Francisco Bay, the USGS is studying processes that influence water and sediment chemistry.

Other Federal Agencies

In addition to the above, other Federal agencies also have programs that affect the estuarine and coastal ocean system. Within the Department of the Interior, the National Park Service manages several coastal and barrier island areas, while the Forest Service manages extensive portions of the Nation's coastal estuarine regions. Also, Interior's Bureau of Land

Management and Minerals Management Service regulate mineral exploration and development in coastal/estuarine areas. The Bureau of Reclamation regulates water and power resource management in the western United States, and the National Science Foundation supports individual investigators to conduct basic research on a wide range of topics that relate to estuarine and coastal concerns. The Department of Energy supports a substantial amount of research on the effects of energy facilities on estuarine and coastal waters.

III. NOAA'S LEGISLATIVE AUTHORITIES

NOAA's authorities to describe and assess estuarine and coastal areas, to conduct research, and to provide information for management have historical roots dating back to 1807, when Congress established the Survey of the Coast. An overview of the legislation that requires NOAA to undertake programs in estuarine and coastal assessment, research, and synthesis/prediction is provided below. A more extensive analysis of NOAA's estuarine and coastal-related legislation is provided in Appendix A.

A. Observation and Assessment

Estuarine observation and assessments describe the coastal environment, its physical characteristics, water and sediment quality, and the animals and plants that depend on these waters for their habitat. The primary laws that give NOAA authority to collect and archive oceanographic, geophysical, climatic, and pollution data include the National Ocean Survey Act (NOSA), the National Climate Program Act, and the Marine Protection, Research, and Sanctuaries Act (MPRSA). Observation and assessment activities also include the development of nautical charts, assessment of fishery stock size and health, and monitoring ambient levels of pollutants in the sediment and water column. These activities are primarily mandated by the NOSA, the Magnuson Fishery Conservation and Management Act (MFCMA), and the MPRSA respectively.

B. Research

NOAA's ongoing estuarine and coastal research efforts emphasize physical processes, ecosystem dynamics, pollutant effects, living resources, and their habitats. Research on the effects of contaminants on estuarine organisms and their subsequent effect on fisheries and human health also constitute a primary focus for many of NOAA's research programs. With respect to physical processes, the NOSA and the MPRSA convey authority to conduct studies in both circulation dynamics and chemical transport. Life-history, disease, and aquaculture studies to support conservation of living resources are governed primarily by the MFCMA and the National Aquaculture Act. Programs designed to identify the importance of habitat and the effects of habitat alterations (including pollution) stem from both the MFCMA and the MPRSA. Finally, efforts to discern the effect of contaminants on food chain organisms and living resources are primarily through the National Ocean Pollution Planning Act, the MPRSA, and the Food, Drug, and Cosmetic Act.

C. Synthesis and Prediction

NOAA encourages wise management of the Nation's estuarine and coastal system by providing synthesis and predictive capabilities, as well as financial support for fisheries conservation and management, habitat conservation, and coastal zone management. Fisheries management includes the administration of interstate grants to assist the states in the development of management measures and protected species programs. Specifically, the Agency synthesizes technical information and develops predictive models to allocate fisheries resources among various user groups and to assess endangered species. These activities stem from the Anadromous Fish Conservation Act, the MFCMA, the Marine Mammal Protection Act, and the Endangered Species Act.

NOAA also synthesizes information on human effects (i.e., habitat alteration and pollution) on estuarine and coastal habitats, and provides extensive recommendations to state and Federal agencies, as well as to private developers based on mandates found in the Fish and Wildlife Coordination Act and the MFCMA. To ensure the management of the coastal zone, NOAA is given authority to encourage and assist states in the development of comprehensive coastal zone management programs, to approve and oversee such programs, and to provide matching grants to the states with approved programs, under the Coastal Zone Management Act. Finally, the National Sea Grant College Program provides the Agency with authority to fund grants for education as well as for advisory services.

IV. ESTUARINE AND COASTAL OCEAN SCIENCE FRAMEWORK

A. Purpose of the Framework

In early 1986, the NOAA Administrator initiated a NOAA-wide planning effort to coordinate and focus NOAA's estuarine and coastal-related programs. The purpose of this effort was to:

1) Define the major estuarine/coastal problems and related issues of national or broad regional concern;

2) Integrate existing NOAA estuarine/coastal-related activities to address the priority issues;

3) Identify those NOAA estuarine/coastal-related activities that may require increased emphasis to address the priority issues; and

4) Provide the basis for the development of a NOAA estuarine/coastal initiative that identifies activities requiring new or enhanced funding.

B. Planning Process

To develop an estuarine and coastal ocean Framework, a committee of representatives from the NOAA line offices gathered information to identify important estuarine and coastal ocean issues. To ensure that the Framework reflected the concerns of academia and state representatives, NOAA's Estuarine Programs Office (EPO) sponsored two workshops that focused on estuarine and coastal research and management needs. Summaries of these workshops are contained in Appendix C.

From these workshop discussions, the NOAA estuarine planning committee distilled the priority issues into four broad problem areas that encompass the breadth of concerns identified and that also conform to NOAA's major programmatic responsibilities. As discribed in the Framework, these problem areas are: 1) alterations in freshwater inflow and circulation; 2) toxic, nutrient, and pathogen contamination; 3) habitat degradation; and 4) the decline of living resources. Within each problem area, questions were developed to identify the information most urgently needed, and strategies were formulated to provide long-term direction for NOAA's programs in estuarine and coastal ocean science. Figure 4 provides a conceptual diagram of the relationships between these general categories.

C. Framework Goal

> To understand and predict natural ecosystem processes to provide the capability to assess the effects of human activities on estuarine and coastal ocean resources.

Because estuarine and coastal ocean systems are affected by both human activities and natural forces, we must determine the relative importance of each in order to effectively manage the resources. The goal statement reflects the fact that the first crucial step toward improved management of estuarine and coastal areas is a better understanding of ecosystem functioning. With improved understanding, we can better predict the impact of human activities on the estuarine and coastal environment.

D. Framework Objectives

Within the context of this stated goal, objectives for each problem have been developed:

Freshwater Inflow and Circulation -- To improve our capability to predict the effects of hydrological forcing on estuarine and coastal ecosystem functioning through increased understanding of circulation and changes in freshwater inflow.

Toxics, Nutrients, and Pathogens -- To define the extent of environmental degradation caused by contaminants in the estuarine and coastal ocean environment and to determine the effects of contaminants on living resources.

Habitat -- To understand the importance of habitat and to predict the effects of habitat loss or physical alteration on populations of living resources.

Living Resources -- To understand the causes of living resource declines and to predict the effects of human activities on populations of important species.

E. Framework Overview

In Figure 5, the priority problem areas and information needs derived from the workshop questions are arrayed under the categories of observation and assessment, research, and synthesis and prediction. These categories comprise the sequence of steps required to address estuarine resource management problems: observation and assessment of existing information, research to answer remaining questions, and synthesis of information to improve our ability to predict the effects of management actions. Components of the Framework have been targeted for potential redirection of existing programs, for program enhancements, or for new funds. Implementation of the Framework will be coordinated by NOAA's Estuarine Programs Office, as discussed in detail in Chapter VI.

V. CURRENT NOAA PROGRAMS THAT ADDRESS FRAMEWORK PRIORITIES

The following is a brief summary of NOAA's current programs in observation/assessment, research, and prediction/synthesis and their relation to the problem areas identified in the Framework. Subsequent chapters of the Framework detail areas where these programs should be augmented or redirected.

A. Observation and Assessment

NOAA's assessment efforts include collecting, archiving, and synthesizing environmental data. The National Estuarine Inventory (NEI), which describes the characteristics of 92 U.S. estuaries, is a major element of NOAA's assessment activities. The NEI includes information on physical, hydrological, and land-use characteristics of each estuary described. This

NOAA ESTUARINE AND COASTAL OCEAN SCIENCE FRAMEWORK

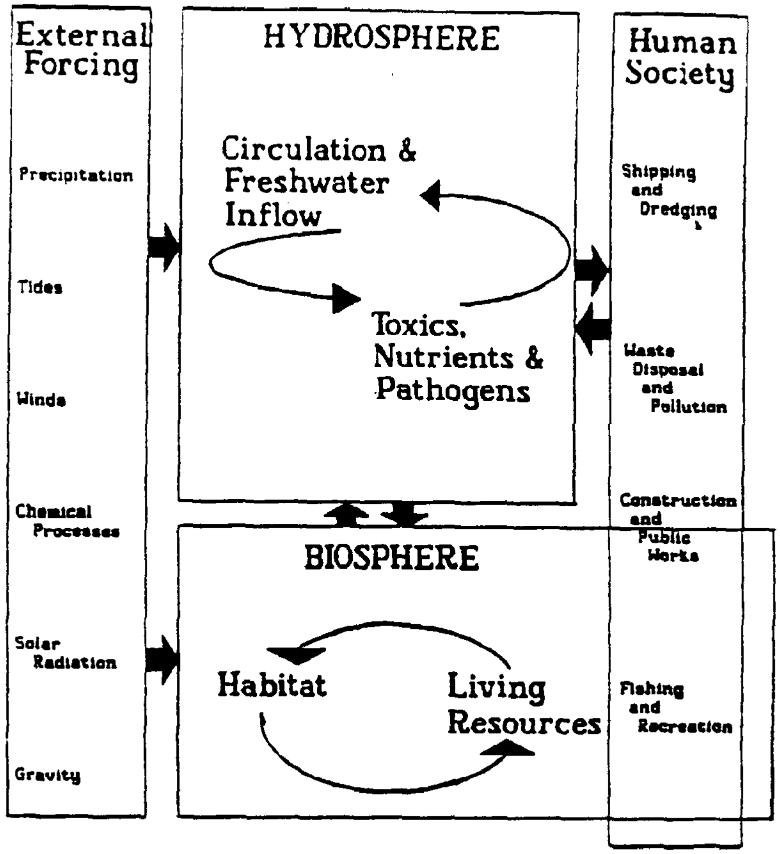


FIGURE 4

Estuarine and Coastal Ocean Science
A Framework for Action

	A. OBSERVATION & ASSESSMENT	B. RESEARCH	C. SYNTHESIS & PREDICTION
Chapter II: CIRCULATION AND FRESHWATER INFLOW	1. hydrological data 2. future inflows	1. forcing functions 2. inflow and fisheries 3. ecosystem functioning 4. episodic events	1. model ecosystem effects 2. apply circulation models
Chapter III: TOXICS, NUTRIENTS AND PATHOGENS	1. sources and rates 2. historical trends 3. toxics effects 4. monitoring environment	1. internal cycling 2. episodic events' role 3. toxics & populations 4. nutrients and productivity 5. pathogens and resources	1. model population effects 2. health concerns 3. contaminated seafood
Chapter IV: HABITATS	1. critical habitats 2. historical trends 3. past mitigation	1. functional value 2. natural variability 3. cumulative effects 4. compensation by restoration	1. model population effects 2. offshore dependency
Chapter V: LIVING RESOURCES	1. historical trends 2. abundance and health 3. economic value	1. key trophic pathways 2. effects on pathways 3. pollution & mortality 4. harvest on ecosystem	1. model population effects 2. cumulative effects, all threats 3. policy option tradeoffs 4. inshore vs. offshore 5. management regulations effects 6. priority estuaries

FIGURE 5

inventory should be updated and supplemented in estuaries where changes in freshwater inflow are particularly problematic for estuarine ecosystem functioning.

Another component of the Agency's estuarine and coastal ocean observation and assessment activities is the National Status and Trends Program, which monitors the key contaminants in selected fish, molluscs, and sediments at 150 sites around the country. The survey compares trends on a national basis and provides a basis for determining whether conditions are improving or worsening. This program should be supplemented in coastal areas where a more detailed understanding of the magnitude of anoxic and contaminants problems is required.

NOAA also assists with data collection and assessment concerning critical habitat types. In an effort to update available information on habitat types, NOAA and its counterpart state coastal management programs are using Fish and Wildlife Service maps to estimate acreage by habitat type and to digitize the information. NOAA is also assessing the acres of wetlands lost since the completion of various surveys by evaluating the adoption of NOAA's permit recommendations to the Corps of Engineers. To provide a stronger basis for making recommendations to regulatory agencies, these and other assessment projects related to habitat should be strengthened as discussed in Chapter IV.

Lastly, NOAA conducts assessments of existing information on important estuarine-dependent living resources. Trends in fisheries recruitment, distribution, and abundance are key to determining the effect of fishing activities, natural variability, and the effects of contaminants or habitat loss on fishery resources. NOAA is developing information on the distribution and abundance of approximately 150 species of estuarine-dependent fish and invertebrates, using an analysis technique developed for the NEI. In some regions, NOAA has also attempted to improve the fishery statistics available from the states for estuarine species through administration of fisheries grant programs. However, historical data on catch and effort are sporadic and vary considerably from state-to-state. In a pilot study, NOAA is working with Maryland and Virginia to conduct stock assessments for key species in the Chesapeake Bay. This model could be used for key species in other coastal areas, using advanced statistical and analytical studies developed as part of this program. For some species, however, information is so poor that data collection on distribution, migration, abundance, and residence may be necessary to undertake even gross estimates.

B. Research

Improving the knowledge of the physical and ecological dynamics that drive the estuarine system is a significant thrust of

NOAA's estuarine research program, along with research on fisheries and the importance of habitats in sustaining these resources. Also important are NOAA's efforts to document the effects of contaminants on food chain organisms, fishery resources, and ecosystem processes. Examples of ongoing research in these areas follow.

Limited resources within NOAA have been allocated to establish the functional value of estuarine habitat types to fisheries productivity. The problem of cumulative effects of habitat loss is of critical importance to sustained estuarine health. Without applied research on the relative importance of major habitat types, it will remain difficult to provide regulatory agencies with the information necessary to demonstrate the cumulative effects of thousands of small-scale habitat alterations on the long-term productivity of the ecosystems.

With respect to contaminants and pathogens, NOAA laboratories are investigating the effects of these agents on the reproductive success of flounder, and are attempting to correlate contaminant levels in the sediment with observations of tumors in fish. By and large, these efforts have been in response to concerns regarding the relatively unknown effects of contaminants on commercially and recreationally important resources in highly polluted estuaries or coastal waters. Additional efforts should focus on ecologically important species and effects of contaminants on fisheries at the population level.

Phytoplankton, rooted aquatic vegetation, and benthic algae are important units of productivity in both the open ocean and the estuaries. Without an understanding of the nutrient cycle in the estuaries, and the natural and man-made perturbations affecting this cycle, effective regulation of nutrient inputs from non-point source runoff and sewage treatment plants is difficult. Moreover, a thorough understanding of the lower end of the food chain will assist the management of fishery resources at the upper end of the food chain. While substantial work on this aspect of estuarine productivity has occurred offshore, little has been undertaken within the estuaries. The few efforts that have addressed certain aspects of productivity should be integrated into a larger study.

To summarize, in the problem areas identified by the Framework, there are significant gaps in NOAA's research activities. These omissions and suggested areas of expanded research are discussed in the following chapters.

C. <u>Synthesis and Prediction</u>

NOAA has only recently begun pilot efforts to address estuarine synthesis and prediction needs. For example, to estimate the cumulative effects of pollution or habitat loss on living marine resources, NOAA has begun an effort to develop models to predict population changes attributable to these factors. NOAA's pollution studies focus on estuarine-dependent species that are exposed to lethal contaminants during their early life in nursery areas. Considerable life-history data are required on estuarine-dependent species to effectively use this approach. Collection of these data should be a priority for prediction of pollution effects. Regarding the effects of habitat degradation on fisheries, current NOAA synthesis efforts include: 1) a simulation model of marsh disintegration and its effects on fisheries caused by loss of interface between marsh and open water and 2) a model to predict salinity distributions and consequent effects on fisheries caused by modified freshwater inflow caused by channelization.

NOAA anticipates that the modeling of environmental processes will become an increasingly important aspect of the Agency's estuarine and coastal programs. Thus, NOAA will continue to devote resources to the development of models that provide the greatest benefit for estuarine and coastal resource management purposes. In addition, NOAA should initiate the development of a hierarchy of models that can be linked to produce a successful estuarine and coastal ocean ecosystem predictive capability. Such an effort is needed if the Agency is to enhance its capability to support complex management decisions that require trade-offs between ecosystem uses. Figure 6 illustrates how such a hierarchy can be used to develop a system-wide predictive capability. In the illustration, a circulation model, a benthic flux model, a near-shore habitat model, and models for non-point and point source pollutants are integrated to determine the effects of various processes on fisheries production.

Components of a System-Wide Estuarine/Coastal Modeling Approach

FIGURE 6

Conclusion

In summary, a variety of current NOAA programs and activities address certain aspects of the estuarine and coastal ocean problem areas described in the Framework. However, priority attention on these specific problems will require increased efforts for some programs, redirected emphasis for others, and some new funding initiatives. Subsequent chapters of the Framework detail these needs for each area; Chapter II - Freshwater Inflow and Circulation; Chapter III - Toxics, Nutrients, and Pathogens; Chapter IV - Habitat; and Chapter V - Living Resources. Chapter VI describes the program integration necessary to transfer NOAA's observation/assessment data, research results, and synthesis/prediction information to estuarine and coastal resource managers at the Federal, state, and local levels.

Chapter II

FRESHWATER INFLOW AND CIRCULATION

OBJECTIVE

To improve our capability to predict the effects of hydrological forcing on estuarine and coastal ecosystem functioning through increased understanding of circulation and changes in freshwater inflow.

PRIORITY QUESTIONS

A. Observation and Assessment

1. What is the existing information base on the hydrological characteristics?

2. What is known about potential changes in freshwater inflow that may influence important estuarine systems in the future?

B. Research

1. How do estuarine forcing functions and physical setting combine to produce the observed circulation and density regimes exhibited by selected estuaries?

2. What are the quantitative relationships between freshwater inflow and fisheries productivity?

3. What is the effect of alterations in natural water inflow and circulation patterns on estuarine structure and function?

4. How do episodic events such as floods influence circulation, sedimentation, and biological processes in estuaries?

C. Synthesis and Prediction

1. What conceptual approaches (models) can be used to assess and predict the effects of freshwater inflow and circulation changes on ecosystem structure and functioning?

2. How can NOAA's modeling capabilites be used not only for navigation but also for improved understanding of ecosystem functioning?

CHAPTER II

FRESHWATER INFLOW AND CIRCULATION

I. OBJECTIVE

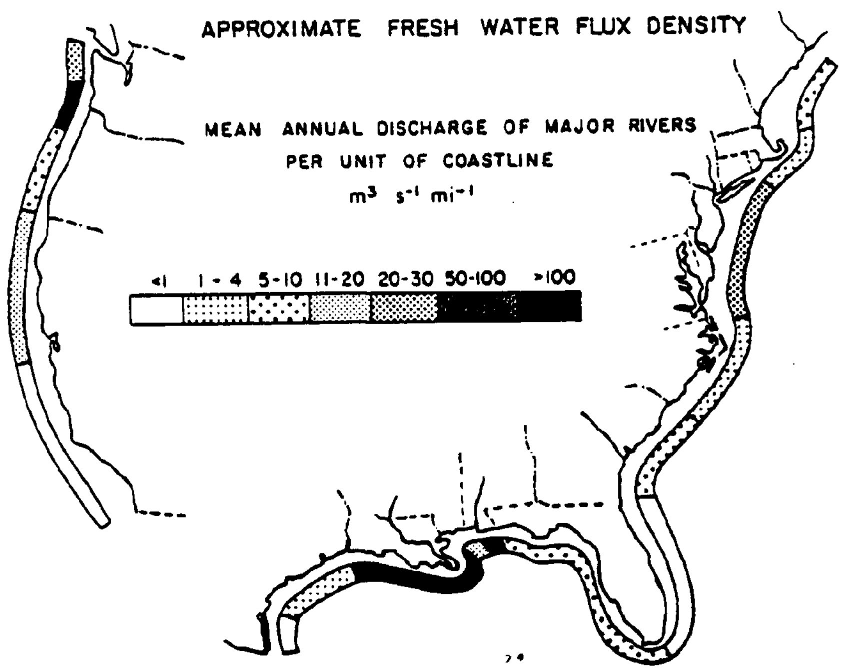
To improve our capability to predict the effects of hydrological forcing on estuarine and coastal ecosystem functioning through increased understanding of circulation and changes in freshwater inflow.

II. PROBLEM DEFINITION

Estuarine waters are driven by a complex set of hydrological forcing mechanisms, such as freshwater inflow, tides and tidal currents, surface wind stress, ocean exchange, and offshore sea level variations. At present, we have little understanding of the relationship of these mechanisms to the productivity of ecosystems. Further complicating our ability to evaluate this relationship, hydrological forcing mechanisms tend to exhibit significant temporal and spatial variability. Advances in our basic knowledge of estuarine dynamics will greatly enhance our ability to predict the effects of hydrological processes on the biology of these ecosystems.

Of particular concern is the alteration of the quantity, rate, and timing of freshwater inflow into estuarine systems by damming or diverting major sources of freshwater that would normally flow into the estuary. Variations of freshwater inflow can have a dramatic effect on estuarine salinity. The salinity of estuarine waters is a major factor in the health and survival of estuarine-dependent fisheries. In addition, as competing upstream municipal, commercial, industrial, agricultural, and recreational demands for water increase, the availability and quality of water to downstream locations is drastically altered. Modern large-scale agricultural operations require enormous volumes of freshwater for irrigation, and their return flows to rivers, streams, and estuaries are generally contaminated with pesticides and toxic pollutants. Land drainage, damming, and channelization of rivers for flood protection or navigation also alter the freshwater supply to estuaries.

Figure 7 shows the approximate freshwater flow for the major rivers of the United States. Alterations of freshwater inflow have resulted in numerous documented negative effects on our estuarine and coastal ocean environments. For example, in San Francisco Bay, freshwater flow was diverted for agricultural and municipal uses, resulting in a marked reduction in water quality and an increase in major anoxia events, especially in the 1950s and 1960s. Projected population growth in the Bay area by the year 2000 will double the ratio of wastewater inflows to freshwater inflow, further complicating an already difficult problem. Even now, the sediments of San Francisco Bay have some of the highest concentrations of DDT and heavy metals in the world. In the Chesapeake Bay, salinities are expected to increase two to four parts per thousand in the next few decades because of projected changes in freshwater inflow. This could have a serious impact on commercially important species such as oysters. Although oysters normally thrive in salty water, so do their parasites and diseases. Estimates of the net loss in oysters because of the rapid spread of these organisms range from 50 percent to 85 percent, under the worst case projections.



Approximate flux of fresh water from major rivers along the coast of the coterminous United States (UNESCO, 1974).

FIGURE 7

Circulation and mixing of estuarine waters are also major factors that control the movement of nutrients and contaminants. Circulation transports salt, heat, sediments, plankton, and contaminants from rivers into the estuary, from one region of the estuary to another, and between the estuary and the coastal ocean. Vertical mixing from wind and wave action, upwelling, and turbulence all mix these quantities into the water column, and influence depletion (dissolved oxygen) or aggregation (plankton blooms) in the estuary.

Estuarine circulation also exerts a major influence on many fisheries stocks. Important species such as striped bass, salmon, blue crab, menhaden, and shrimp have larval forms that either develop in or pass through the mouths of estuaries. Seventy percent of the U.S. commercial catch is composed of species that are considered estuarine-dependent. For these species, larval recruitment and success of the resulting year class depend in large part on the circulation dynamics of estuaries and the associated coastal ocean waters. NOAA research has shown a direct relationship between blue crab spawning and circulation in Chesapeake Bay. Further research on the relationship between circulation and biological populations needs to be conducted.

III. STRATEGY

NOAA's strategy for improving our capability to predict the effects of hydrological forcing on estuarine functioning is described in terms of observation assessment, research, and synthesis/prediction. The primary needs are: A) assessment of existing information on estuarine circulation and hydrological forcing functions; B) research on the underlying dynamic relationships that affect selected estuarine environments and the quantitative relationships among estuarine hydrodynamic characteristics, contaminant fate, and fisheries productivity; and C) synthesis of available information on the relationship between estuarine forcing functions and effects on critical living marine resources.

A. Observation and Assessment

1. **What is the existing information base on the hydrological characteristics of major U.S. estuaries that can be used for comparative studies to assess ecosystem functioning?**

Underlying an understanding of the water quality and biota of estuaries is a knowledge of the hydrological processes that affect them. Estuaries are by definition mixtures of freshwater and saltwater that produce a unique salinity regime depending on the balance between the quantity of freshwater inflow and the magnitude of saltwater mixing. The salinity regime is further influenced by processes within the estuary, such as meteorologically induced water movements that account for the majority of water exchange with the ocean in shallow bays that have weak astronomical tides. These processes also include density currents that may account for substantial movement of high salinity water into the estuary.

A number of processes -- river inflow, tidal exchange, wave action, storm tides, and density currents -- can be considered to be physical forcing functions causing the estuary to exhibit the observed circulation and density (salinity/temperature) regime. Because the magnitude of these forces changes in time and space within an estuary and from estuary to estuary, it is not possible to measure currents and salinity in one estuary and expect to apply the results directly to another. It is possible to understand the relative impact of each of the forces on a specific estuary, to judge which of the forces are most influential on the transport processes and subsequently the water quality and biota in the estuary, and to incorporate that information into models. It is therefore important to assess existing information on the hydrological characteristics of estuaries as an aid to understanding and eventually predicting estuarine structure and functioning. With this in mind, it is recommended that a national inventory of the hydrological characteristics of major estuarine systems be developed. This has been accomplished in part through the development of the National Estuarine Inventory. However, a more intensive effort is warranted. For instance, the inventory should also be organized on a computer-based data system and should define, in a systematic and comprehensive manner, estuarine salinity regimes, freshwater inflow volume and rates, tidal prism information, and other important hydrological characteristics. This inventory, when adapted to a computer-based data system, will provide analytic capabilities and serve inter-estuarine comparative needs for assessing relative ecosystem functioning for representative types of estuaries.

2. What is known about potential changes in freshwater inflow that may influence important estuarine systems in the future?

Freshwater inflow is a major estuarine process that influences habitat, the physical estuarine environment (e.g., circulation, salinity/density distribution), contaminant fate, and resource distribution. Changes in freshwater inflow can therefore have a major influence on important estuarine functions. Priority areas related to this question include assessing future plans for freshwater flow alterations and potential concerns in major watersheds where freshwater inflow is a problem for estuarine ecosystem function, such as San Francisco Bay, Albemarle Sound, and along the Texas Coast. Assessments of the influence of such alterations should be made on the basis of known impacts in other watersheds that have been subjected to flow diversions.

B. Research

1. How do estuarine forcing functions (inflow, wind, tides, etc.) and physical setting (temperature, salinity, bathymetry, etc.) combine to produce the observed circulation and density regimes exhibited for selected types of estuaries?

Research must be conducted to understand the combination of conditions that produces unique hydrodynamical environments. The research will include modeling of selected types of estuarine systems combined with a measurement/verification program. A portion of this work is ongoing in the NOAA "core" estuarine program. Core enhancements and new monies will lead to the important advances for this problem area especially in the area of model development and the application of new measurement technology. Priority tasks include:

1a. Define how the major estuarine forcing functions affect estuarine structure and functioning for selected types of estuaries.

Studies are needed in estuaries of different sizes, bathymetries, climate regions, and types that consider all major forcing functions (e.g., inflow, wind, run-off, ocean exchange, etc.) as they relate to circulation, mixing, and internal density changes.

This should be done in a three-dimensional format to ascertain vertical structure in time and space over reasonably long periods of time. We need to understand the relative impact of each of the forcing functions, judge which are most influential for various estuarine types, and determine the water quality and biological response. To incorporate this information into predictive models requires a substantial amount of information on the meteorological, tidal, and storm surge characteristics of the estuary as well as freshwater and oceanic inflow.

1b. Determine the importance of freshwater inflow and circulation to the dynamics of selected estuarine systems.

Freshwater inflow and circulation are critical factors related to estuarine functioning. Measurement programs now under development could supply the necessary information to improve our understanding of the importance of these hydrological factors. A major problem exists in the measurement of the flux of important quantities through cross-sections in estuarine systems. The principal difficulty arises from the very small percentage of area in which conventional measurements are actually made in a cross-section of a given estuary. Current meters, for example, provide only point measurements of limited duration. Advances in acoustical measurement technology have demonstrated that it is possible to observe layering in estuarine systems acoustically and to provide integrated current measurements for individual layers. Studies are being carried out to determine if it is possible to measure salt flux acoustically as well. Acoustical measurements can provide integrated values of currents in long time series formats across estuarine layers. The combined use of recent advances in measurement technology and hydrodynamical modeling would represent an effective approach to the determination of the relative importance of freshwater inflow and circulation for selected estuarine dynamic systems.

1c. Determine the importance of estuarine dynamical process to selected estuarine functions.

Transport of nutrients and other materials between estuaries and associated coastal waters is important in determining the fate of contaminants, changes in habitats, the biological productivity of the estuary, and fishery recruitment. The exchange of nutrient-rich waters and sediments has important consequences for early life-stage marine organisms and vegetation. The larvae of many estuarine-dependent species are transported between estuaries and coastal waters by local circulation. Estuarine circulation and freshwater inflow patterns determine the distribution of sediments and contaminants within the habitat. Therefore, research must be conducted on the importance of selected estuarine dynamical processes to selected estuarine functions, such as contaminant flushing, habitat, and fisheries.

2. What are the quantitative relationships between freshwater inflow and fisheries productivity?

Estuarine hydrodynamics influence the productivity of estuarine-dependent fishery species. Our understanding of fundamental relationships must be applied to the predictions of changes in fisheries production that may be due to man-made changes in the magnitude or timing of freshwater flow to estuaries. Identifying the controlling mechanisms and quantifying specific effects of water management activities (such as agricultural, municipal and industrial diversions of freshwater, dam construction, and wetland drainage) will be necessary in order to manage fisheries.

There is evidence to indicate that relationships between freshwater inflow and fishery production (or species abundances) can be either positive or negative, depending on the species and the estuary. The relationship depends upon the range of water flow relative to the volume capacity or tidal prism of the estuary, the shape of the estuary, and its location relative to prevailing winds and storms. Also, the seasonality of inflows appears to be important. Research efforts should consider all possible factors to determine the mechanisms responsible for the effects of freshwater flow variations on indicators of fisheries-related productivity.

3. What is the effect of alterations in natural water inflow and circulation patterns on estuarine structure and function?

Spatial and temporal variation in salinity, largely determined by circulation and freshwater inflow, constitutes one of the most significant physical parameters influencing contaminant and biological distributions within estuaries. Variability in circulation and freshwater inflow volumes can also alter the location and size of nurseries or habitats. Migration and spawning patterns may be keyed to circulation, river flow, or salinity, and these patterns can be interrupted, organisms can be flushed out of a system and/or find it uninhabitable as a result of variation in flow. Thus, there appears to be considerable coupling between flow patterns and both the distribution and abundance of organisms, and the availability of nutrients.

However, knowledge of the degree of coupling, the relationship between chemical and biological processes, the timing, and the variability of flow is limited. Alterations of freshwater inflow patterns can compound already complex dynamical interactions about which we have less than adequate scientific information. Knowledge of the details of biological responses to seasonal inputs and variations in flow is mandatory if we are to understand the effects of circulation and freshwater inflow on estuarine systems. Priority tasks for this area of study include:

3a. Determine how freshwater inflow affects turbidity in estuarine systems.

The estuarine location where freshwater inflow velocity equals the bottom density current is called the null zone. Because of relatively strong vertical motions, the null zone tends to have high concentrations of sediment and organic particulate matter in the water column, making it a region of high biological productivity. The position of the null zone is controlled partly by estuarine density dynamics, but largely by freshwater discharge. The relation between productivity and null zone characteristics is a topic of needed research.

3b. Determine how circulation patterns and freshwater inflow affect estuarine habitat types and productivity.

To effectively manage estuaries, one must have the capability to predict currents, water quality, and biological populations that change because of natural and human-induced alterations in the physical forces that drive the system. Changes in freshwater inflows (from extreme drought conditions to major floods with upstream storage reservoirs), tidal regime (due to physical modification), sea level (short-term and long-term), and the morphology of the estuary (dredging and filling) are examples of alterations that affect currents. Models offer great potential for use in estuarine management because they can be used to forecast the effects of various management scenarios related to circulation, freshwater inflow, water quality, biological populations, primary and secondary productivity, and nutrient cycling. Relationships between circulation, freshwater inflow, and important processes for selected estuarine systems must be studied in order to understand how these functions affect habitat types and productivity.

4. How do episodic events such as floods influence circulation, sedimentation, and biological processes in estuaries?

It has been demonstrated that extreme events such as floods, hurricanes, and winter storms can dominate estuarine sedimentation and biological processes for short periods of time, that they can dominate sedimentation and biological transport rates over longer periods of time, and that if they lead to changes in basin geometry, their effects can be persistent. Less extreme events such as freshets may play even larger roles in controlling sedimentation processes and patterns. Research areas that need to be addressed include storm and tidal energy dissipation, the effect of extreme flow events on filtering efficiency, and the importance of storm events in releasing nutrients and contaminants from sediments to the water column. A priority task of study is the relationship between flooding events and both estuarine sedimentation and biological processes. Sedimentation processes in estuaries are extremely variable in time and space.

They not only undergo tidal and seasonal cycles but are occasionally disturbed by major storms or floods that can dominate the sedimentation of the system, or at least segments of it. Because of these vagaries, it is frequently more effective to begin an investigation of estuarine sediment systems by examining the end products of these processes rather than the alternative. To date, there have been few timely studies of actual episodic events regarding estuarine processes. We do know that these extreme events can dominate an estuarine system in the short-term and their impact can be observed over longer periods of time. However, the relative importance of these infrequent events needs to be evaluated if we are to understand the impact of human activities on the physical and biological system. Specifically, research needs to be done on the relationship between flooding events and both estuarine sedimentation and biological projects.

C. <u>Synthesis and Prediction</u>

1. What conceptual approaches (models) can be used to assess and predict the effects of freshwater inflow and circulation changes on ecosystem structure and functioning?

Priority tasks include developing conceptual approaches (models) that can be used to predict the effects of freshwater inflow on populations of important living resources. Another area of study is understanding what improvements in present hydrodynamical modeling capabilities can be used to better predict the fate of contaminants, sediment transport, and biological effects in estuarine systems.

Projects should also be initiated to evaluate and synthesize relevant data and then to develop and test conceptual approaches (models) that can be used to relate human-caused stress and natural factors for selected estuarine systems and selected species. Specific projects to be addressed include: a summarization and evaluation of data for selected estuarine fisheries to document the levels of variability in population parameters; an evaluation of information documenting effects of stress on selected fish population parameters; developing population models to evaluate the relative impacts of various stresses and environmental management strategies on selected fishery stocks; summarizing and evaluating data describing ecosystem changes (e.g., compensation) that occur when the abundance of a key species is changed; and developing models to evaluate system impacts that may occur because of environmental or fishery management strategies.

2. How can NOAA's modeling capabilities for navigation, meteorological forecasting and economic assessment be used for improved understanding of estuarine-coastal ecosystem functioning?

Existing hydrodynamical models for assessment of physical-biological interactions including drift, transport, and recruitment of marine species can be adapted to specific estuarine research needs. In addition, the simulation of salinity and temperature in these models can be adapted to other water column constituents such as nutrients and contaminants. Available models of blue crab larval drift can be extended to other marine species that have an estuarine-dependent life stage, such as oysters, and can also be adapted to include more complex behaviors such as swimming, and even to sediment transport. The use of remotely-sensed estuarine characteristics such as sea surface temperature, turbidity, and chlorophyll can be applied to monitoring important changes and the calibration/verification of hydrodynamical models.

For decades, meteorologists have made use of fluid-dynamical models to predict weather. In addition, NOAA meteorologists have been able to integrate satellite remote sensing data into their forecasting analysis procedures. It is hoped that the NOAA expertise in fluid-dynamical modeling of the atmosphere and the application of remotely sensed data can be utilized to improve our understanding of the effects of hydrodynamical forcing (especially those that are meteorological in nature) on estuarine systems.

In addition to modeling, accurate data and information on the currents and water levels in estuaries are vital to the understanding of the transport of sediments, nutrients, contaminants and fish larvae. Recent developments in measurement technology and telemetry have enabled scientists to obtain accurate data on estuarine current and water level conditions. These data can be used in their own right for navigation-related uses or to verify numerical models of estuaries. The capability to predict tides using a numerical model for navigational purposes was demonstrated in Delaware Bay, but cost, personnel, and computer hardware constraints made this impractical for long-term operation. It may yet be possible in the future, given the declining cost of hardware, to apply this type of model to selected estuaries. Numerous management applications, only some of which are discussed above, can be investigated using hydrodynamic models similar to those used by NOAA for meteorological and tidal predictions.

Chapter III

TOXICS, NUTRIENTS, AND PATHOGENS

OBJECTIVE

To define the extent of environmental degradation caused by contaminants in the estuarine and coastal ocean environment and to determine the effects of contaminants on living resources.

PRIORITY QUESTIONS

A. Observation and Assessment

1. What are the sources and loading rates of nutrients, toxics, and pathogens in estuarine and coastal waters?

2. What is the current status and significance of toxic, anoxic, and pathogen distribution?

3. What statistical data are available to relate contaminant exposure to living resources?

B. Research

1. What is the internal cycling of contaminants?

2. What is the role of episodic events?

3. What are the effects of toxics on estuarine organisms?

4. What are the effects of nutrient loadings on ecosystem productivity?

5. What are the effects of pathogens on estuarine resources?

C. Synthesis and Prediction

1. What conceptual approaches (models) can be used to relate contamination of broad areas of estuarine habitats to population changes for representative species of concern?

2. How can information transfer and predictive capabilities be improved to better inform the public of the consequences of fisheries contamination on harvest and marketability?

Chapter III

TOXICS, NUTRIENTS, AND PATHOGENS

I. OBJECTIVE

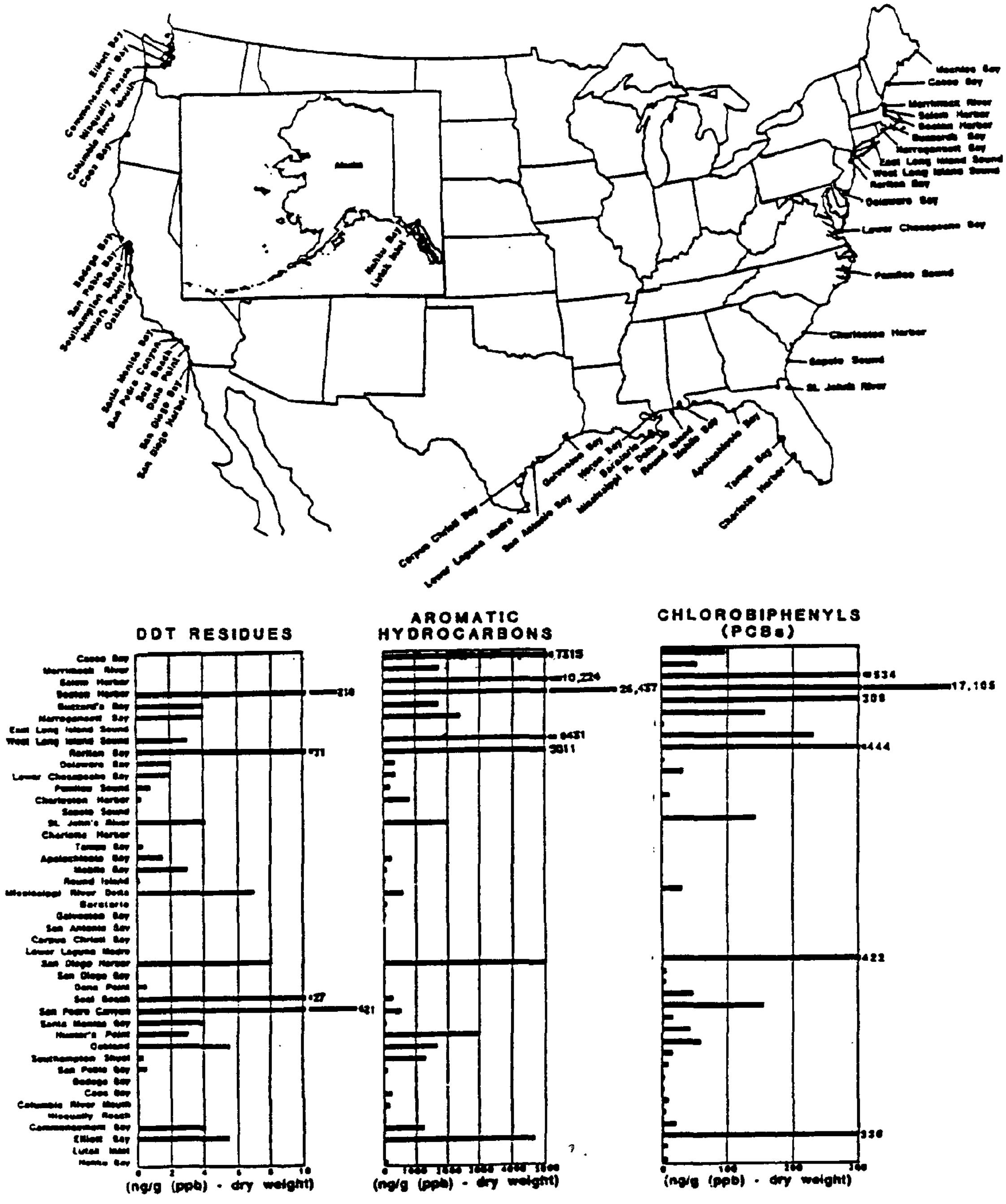
To define the extent of environmental degradation caused by contaminants in the estuarine and coastal ocean environment and to determine the effects of contaminants on living resources.

II. PROBLEM DEFINITION

A variety of contaminated materials is introduced into the estuarine waters of the United States as the result of increased human activity along the shorelines. These materials often include contaminants that are a serious threat not only to the estuarine ecosystem, but also to human health. Studies show that there is considerable contamination in the biota, water column, and the benthos associated with estuarine systems nationwide, especially within those bodies of water adjacent to major urban centers. Figures 8, 9, and 10 summarize these findings. Figure 8 illustrates the results of the NOAA Status and Trends Program, which found high levels of toxic materials in the sediment of urban estuaries. Figure 9 shows that estuarine and coastal areas experiencing hypoxia (low oxygen concentrations that can be traced to nutrient enrichment) are located adjacent to population centers that discharge sludge into the surrounding waters. Finally, Figure 10 shows the correlation between coprostónol (a compound found only in human waste) and the closure of shellfish grounds.

Human activities and waste products introduce many different contaminants to estuaries, including toxic chemicals and metals, nutrients that can cause eutrophication, and a number of human pathogens. Some of these substances occur naturally, but the rates and amounts of these materials cycling into estuarine environments are sometimes increased by human activities. This pattern is valid for many naturally occurring elements and chemical compounds, including plant nutrients, heavy metals, and a number of organic compounds. Other chemicals, primarily a great variety of organic compounds, do not exist to any appreciable extent in a natural state, and are present in the environment only because of industrial activity.

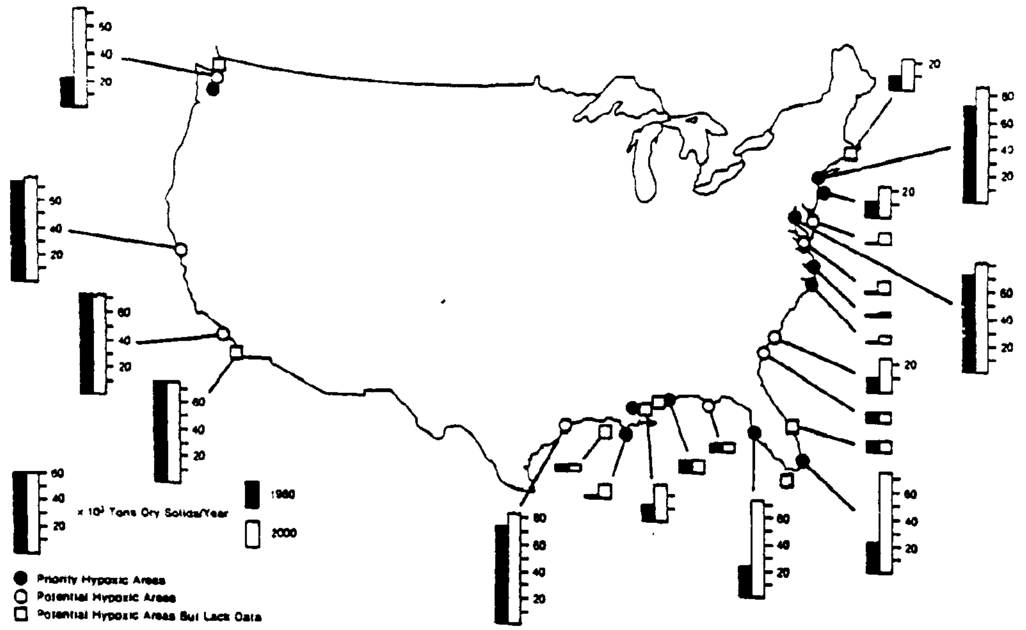
CONCENTRATIONS OF TOXICS IN ESTUARINE SEDIMENTS



(From NOAA's NS&T Progress Report, Benthic Surveillance Project, 1984)

FIGURE 8

HYPOXIC AREAS & SLUDGE PRODUCTION IN ESTUARINE & COASTAL WATERS OF THE UNITED STATES



(Sources: US DOE-BNL/NOAA, Nationwide Review of Hypoxia,1986 and NOAA/NOS, Identifying and Evaluating Alternative Ocean Dump Sites, 1982)

FIGURE 9

SHELLFISH CLOSURES & SEWAGE TRACER LEVELS IN SEDIMENTS

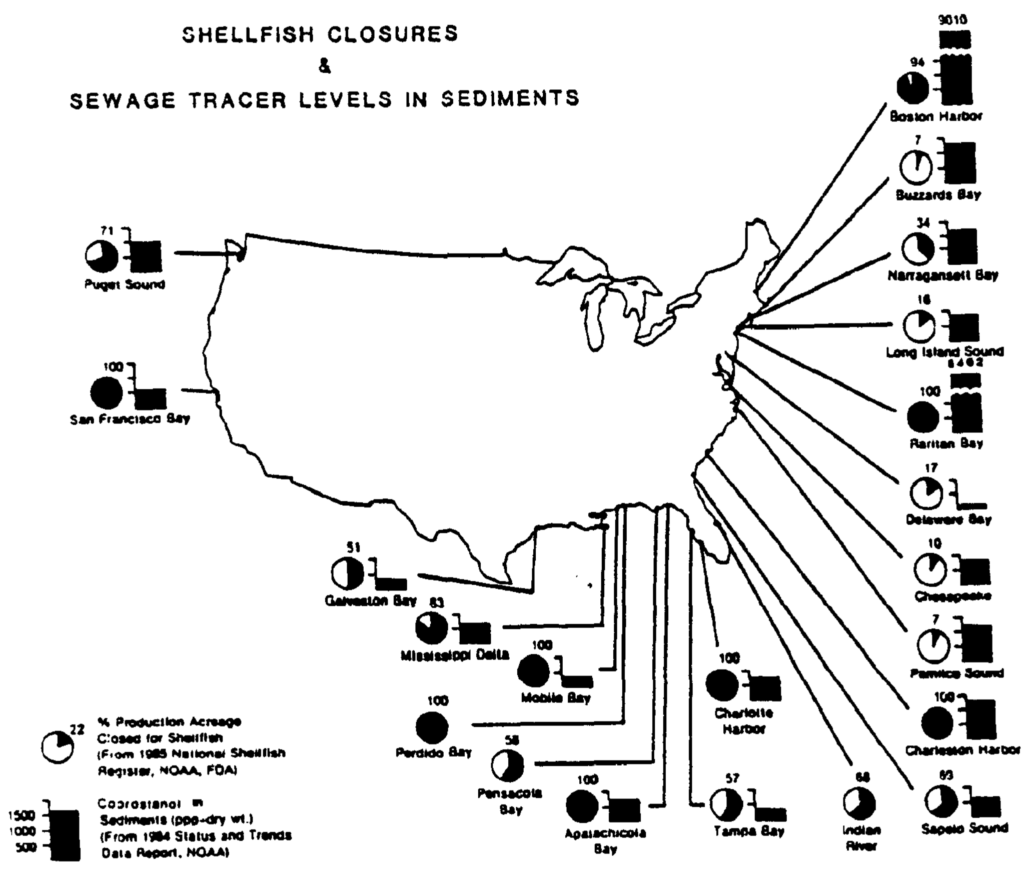


FIGURE 10

The addition of nutrients, metals, organic compounds, and pathogens to estuaries threatens the health of estuarine ecosystems and contaminates seafood. Nutrient over-enrichment can cause shifts within the biological community to less desirable species and stimulate nuisance growths of algae and depletion of oxygen when these growths decay, frequently with attendant kills of fish and other resources. The primary threat of the metals and organic compounds is their potential toxicity to marine organisms and to humans. Many of the contaminants -- for example, heavy metals such as cadmium and copper, and synthetic organics compounds such as DDT and PCBs -- are toxic to marine organisms and humans even at low concentrations, i.e., parts per billion to parts per million. Pathogens associated with wastes from human activities, especially sewage treatment, present a threat to humans for periods ranging from a few hours to weeks and possibly longer periods after their introduction into the marine environment. Humans can contract a variety of disorders, including serious diseases such as hepatitis, if they become infected with pathogens while swimming or through the consumption of contaminated fish or shellfish.

To protect human health and the marine environment from the threat posed by contaminants that enter the estuarine ecosystem, we must improve our understanding of the behavior and effects of such materials. This knowledge will assist in the development of improved ways to manage and control contaminant inputs to estuaries. Knowledge is needed regarding the sources and magnitudes of contaminant additions and how these materials are transported and altered after they enter the environment. Major efforts are needed to understand the effects of contaminants on marine species at individual, population, and community levels. With improved knowledge, we will significantly increase our capability to predict the consequences of existing and proposed control measures for contaminants and enhance our ability to cope with these contaminants wisely.

III. STRATEGY

The strategy for meeting these needs includes: 1) observation and assessment to identify point and non-point contaminant sources, monitor the trends of contaminant concentration; 2) research to understand and model the physical and biological processes that transport contaminants; and 3) synthesis to describe the responses of living marine resources to contaminant loading and habitat degradation. Using the above information we will be able to accurately assess the threat to ecosystem functions posed by toxics, nutrients, and pathogens.

A. Observation and Assessment

1. What are the sources and loading rates of nutrients, toxics, and pathogens in estuarine and coastal waters?

Efforts are needed to identify the sources of estuarine contamination and to quantify the magnitude of the relative and absolute amounts of these materials coming from various sources. The National Coastal Pollution Discharge Inventory (NCPDI) represents a first attempt to collate and quantify these figures.

The contributions from non-point sources, such as those associated with land runoff and atmospheric inputs, are very difficult to determine at present. Efforts to improve the means to make such source measurements should include identification of the physical and chemical forms of the contaminants from the various sources. In this area, remote sensing vehicles equipped with spectrally correct color scanning equipment could aid in the tracking of sediment plumes and algal blooms associated with eutrophication. A large suite of equipment is available for this purpose. Airborne units include LIDAR (a flourescence detection system which can determine the types of phytoplankton in the water column) and the Multi-channel Ocean Color Sensor (MOCS, a spectroradiometer using visible imaging and the Aircraft Ocean Color Instrument). High altitude color photography is also possible using the NASA high altitude aircraft.

2. What is the current status and significance of toxic compound distribution, nutrient, and pathogen distribution affecting U.S. estuaries?

Until quite recently, there was no nationwide program to regularly assess the status and trends of the pollution problems in U.S. estuarine and coastal waters or to interpret such information in terms of the overall ecological health of these areas. NOAA has recently instituted a program in response to this need. Such efforts need to be expanded both temporally and spatially in order to determine the severity of pollution problems in estuarine areas that are most in need of research and management actions.

There are also efforts underway to search for perturbations that can be traced to contaminant loading in the estuarine environment. An accurate baseline must be established from which variations in contaminant loading can be measured and trends assessed. Historical data represents one of the great untapped resources available to establish such baselines. EPA and other agencies (NASA, Navy, NOAA, etc.) have archived tremendous amounts of data over the years in computerized files. Using this information, investigators would not only be able to establish meaningful "zero points" above which future trends could be measured, but would also be able to examine a host of important historical characteristics. Priority needs include:

2a. Determine the extent of hypoxia in coastal and estuarine waters.

In a nationwide study conducted by NOAA, hypoxic areas were identified in coastal and estuarine waters. Priority concern was assigned to those regions that exhibited severe or repeated hypoxia and/or eutrophication. In the cases studied, hypoxia occurred as a result of stratification (particularly due to salinity differences in estuaries) combined with excessive nutrient loading (point and non-point) and phytoplankton production and decay. These conditions, combined with poor flushing, circulation, and/or calm wind conditions helped to determine the duration of the hypoxic conditions and stresses on benthic organisms. There is sufficient evidence to suggest that severe hypoxic conditions result in mass mortalities among sessile shellfish and some bottom-dwelling finfish species. These conditions disrupt the economic system through the loss of fish catches and cause increased ecological stress by decay of the affected fish populations. Therefore, future efforts should address not only the problem of hypoxia monitoring, but should also be concerned with the accurate prediction of such conditions. In this case, as with many others, an examination of historical data might provide the clues necessary to point the way toward a viable solution for hypoxia forecasting.

Coastal areas identified as having severe hypoxia were the New York Bight/New Jersey Coast and the Louisiana Coast west of the Mississippi in the Gulf of Mexico. Estuaries identified as having severe hypoxic problems by region, were:

Northeast:
Hudson-Raritan/East River/Western Long Island Sound and Northern Chesapeake Bay

Southeast:
Western Albemarle Sound/Upper Neuse River/Biscayne Bay

Gulf of Mexico:
Tampa Bay/Perdido Bay/Mobile Bay/Lake Pontchartrain

West Coast:
Budd Inlet in Puget Sound

2b. Determine the extent of toxic materials in bottom sediments of coastal and estuarine systems.

The increased industrialization of the coastal areas of the United States has resulted in elevated levels of toxic materials (PCBs, heavy metals, etc.) in adjacent coastal waters. New York, Boston Harbor, and Commencement Bay, Washington, are examples of areas heavily impacted by pollutants that can be traced to increased human activity. It is reasonable to project that additional areas will come under the influence of these materials as the population pressures on the shoreline and its resources increase. The increase in pollution will particularly affect the Southeast and Gulf coasts, where 94 and 98 percent of their respective commercial harvest is composed of estuarine-dependent species. PCBs can now be found throughout the coastal and shelf waters of the Northeastern United States and have resulted in the closure of commercial fishing for striped bass in the Hudson River.

NOAA's estuarine programs must include the continuous monitoring of areas in which there is a known contaminant impact. Such observations are necessary in order to determine the increase or decrease in concentrations of various toxics. In addition, sampling should include areas outside those showing the most serious degradation, so that any movement of materials attributable to sediment transport or other factors can be quickly determined. Finally, relatively pristine areas should be sampled to ensure that they have not become contaminated. If toxics or pathogens are found at low levels in what was previously a "clean area", immediate steps must be taken to identify the source of these pollutants and avert a more serious problem.

2c. Determine the distribution of pathogens as represented by closed areas or diseased organisms.

There are several types of pathogens, including those associated with sewage sludges and bio-toxicants such as "red tide" organisms. There is evidence of contamination by pathogens in all of the major industrialized estuaries. Pollution-related closures of shellfishing grounds generally occur because of pathogens associated with human waste (coliform bacteria). In fact, the coliform "most probable number" is an index used by most authorities to make decisions regarding the closure of fishing or swimming areas. At present, there are many areas throughout the country where shellfishing and finfishing are banned. Notably, the New Bedford, Massachusetts area recently underwent a closure involving 28 square miles. The increased number of areas closed to fishing is another rough index of a problem that managers of coastal and estuarine areas must resolve. This data provides the baseline from which increased degradation or recovery can be measured. Such information can be portrayed graphically, on maps or charts, and can serve as a valuable management tool.

There may even be ways in which these data could serve as sign-posts, pointing to possible pollution sources. In addition, as the areas decrease in size, through the application of wise management techniques, the results can be distributed in a readily understandable format. NOAA has initiated a project to determine the basis for shellfish harvesting limitations in estuaries around the Nation and to identify sources of pollution in those estuaries where harvest limitations are due to pathogens. The results of this project should be helpful in addressing the more general problem discussed above.

3. What statistical data are available to relate contaminants exposure to living marine resources?

A comprehensive information base on the effects of contaminants on living resources exists in the extensive assortment of published and grey literature. These data need to be synthesized with respect to their use in helping to understand how contaminant exposure affects living marine resources.

B. Research

1. What is the internal cycling (availability, transformation, and residence) of toxics, nutrients, and pathogens?

Although pollution studies have clearly shown that many of our estuaries are contaminated, they did not determine the full extent of impact throughout the ecosystem. Thus, in general, we have an incomplete understanding of the present extent and magnitude of estuarine and coastal water contamination, and the relative and absolute contributions of different point and non-point sources. The difficulties in tracing a contaminant from its sources to its effect on the estuarine system are further complicated by a lack of knowledge concerning the fate of these materials after they enter the estuary and the various forms in which the contaminants enter the estuaries. Priority needs include:

1a. Define the mechanisms that control the fate and transformation of toxics, nutrients, and pathogens in estuarine and coastal systems.

After entering an estuary, contaminants are transported by chemical, biological, and physical processes. In order to improve predictions concerning the transport, transformation, and fate of contaminants in estuaries, field and modeling studies of water movements, including such processes as tidal mixing, wind forcing of estuarine circulation, and vertical dispersion, are required (see Chapter II). Efforts to improve our understanding of the role of other processes such as volatilization and photolysis in determining contaminant distributions are also needed. A more complete knowledge of the role of sorption of contaminants on particles in determining the transport and ultimate fates of these materials is especially required.

During their physical transport, chemical contaminants often undergo transformations by chemical and biological processes into new chemical species and physical forms that may represent an increased or decreased environmental threat in terms of toxicity or nutrient enrichment. Therefore, studies on how biological and chemical processes change the physical and chemical states of various contaminants as they move through estuaries should be conducted in concert with the physical process research. These studies should include efforts to develop a better understanding of the important chemical reactions that help determine contaminant forms and concentrations in the environment. Research concerning the association/disassociation of contaminants to form chemical complexes with other components in estuarine waters and how the formation of these complexes affects contaminant toxicity is needed, as is research on how biological processes, especially those caused by bacteria and other micro-organisms, can alter the types and amounts of contaminants. Because pathogens are living organisms, studies on these contaminants need to establish their survival, reproduction, and distribution pattern.

Finally, in order to use our knowledge concerning contaminant fates, transformations, and transport to help solve environmental problems, there is a great need to improve our capabilities to estimate or predict the actual distributions in space and time of contaminants so that the exposure of living resources to contaminants can be determined. Relevant subtopics include: 1) determine the diagenetic processes that control the absorption and desorption of contaminants by particles and 2) determine how diagenetic processes affect pore water composition of the overlying water.

1b. Define the role of fine grained sediments in the fate and transformation of toxics, nutrients, and pathogens.

Many of the most insidious contaminants are relatively insoluble in water and have a high affinity for fine particles. The low concentrations of dissolved metals in estuarine waters may be the result of this affect. Once contaminants are absorbed, their distribution, transport, and accumulation are affected, and indeed may be controlled by the estuary's sedimentation processes. The partitioning of contaminants among the water, sediments, pore waters, and biota, however, may change as sediments and their associated contaminants are exposed to different environmental conditions by natural physical, geological, chemical, and biological processes. Relevant subtopics to be addressed include: 1) determine to what extent and by what mechanism the distribution of contaminants in an estuary are controlled by the transportation and accumulation of fine-grained sediments and 2) determine how periodic resuspension of sediments affect the absorption and desorption of particle-associated contaminants.

1c. Define the role of organisms in determining the fate, transport, and transformations of toxics, nutrients, and pathogens.

Studies are needed to develop a better understanding of the pathways and rates of nutrient and toxics cycling through the different trophic levels of estuarine ecosystems. Such studies should emphasize the biological and physical-chemical processes that control dynamics of nutrient regeneration and distribution within estuaries and the relative importance of these internal processes in controlling biological production as compared to the importance of additions of nutrients from external sources.

2. What is the role of episodic events such as floods, storms, and hurricanes on sedimentation and the associated contaminant fate in estuarine and coastal systems?

Sedimentation processes in estuaries are extremely variable in time and space. Sedimentation not only undergoes tidal and seasonal cycles, but also is occasionally influenced by major storms or floods that may dominate the sedimentation process in estuarine systems. We know that these extreme events can cause major short-term changes in the sedimentation process; they also can have major effects on estuarine and coastal ocean systems over longer periods of time. However, the relative importance of these infrequent events needs to be evaluated if we are to understand the impact of human activities on the system. Priority needs include:

2a. Develop institutional mechanisms to study rare and unpredictable storm events.

The study of storm events that may exert a controlling influence on estuarine sedimentation is hampered by two problems. One is the technical problem of maintaining instruments to measure conditions for very long, relatively uneventful periods in order to observe rare but significant storm conditions. The second problem is the inability of traditional funding mechanisms to respond quickly enough to ensure that observations can be made in the critical period during or immediately after storms.

There is a need for establishing a coordinated research plan that can be implemented quickly for studying storm events. This plan should have application to estuaries and coastal areas in addition to a wide variety of other applications.

2b. Determine conditions under which episodic events control the distribution of particle associated contaminants.

It has been demonstrated that extreme events such as floods and storms can dominate estuarine sedimentation processes for short periods of time, that they can dominate sedimentation rates over longer periods of time, and that if they lead to changes in basin geometry, their effects on circulation and sedimentation can be persistent. Less extreme events, such as freshets and severe storms may play even larger roles in controlling sedimentation processes and patterns. Research areas that need to be addressed include storm and tidal energy dissipation, the effect of extreme flow events on filtering efficiency, and the importance of storm events in releasing nutrients and contaminants from sediments to the water column.

3. What are the effects of toxics on populations of important marine organisms?

Additional research is needed to improve our understanding of the effects that various toxic contaminants and nutrients have or could potentially have on estuarine ecosystems and living resources. Studies on toxic contaminants need to go beyond laboratory toxicity studies and should focus on effects of contaminants on organisms and populations. Innovative means to evaluate toxicity under actual or simulated field conditions need to be developed and used for a wide range of estuarine situations. Also, the present efforts to shift emphasis away from relatively short-term studies concerned with acute toxicity to longer-term research projects concerned with chronic, sublethal effects need to be continued and strengthened. These longer-term studies should focus, not just on the effects of contaminants on individual organisms, but also on how these contaminants influence the entire ecosystem. Priority studies should include the following:

3a. Determine valid indicators of stress (lethal and sublethal) on important species because of exposure to toxic contaminants.

Stress may be evaluated within the marine environment in much the same way as it is in terrestrial environments. Examinations of individual organisms may reveal lesions and deformities because of malformations of spinal cords and other structures. Microscopic and enzymatic analysis may reveal malfunctions in the energy utilization or reproductive system of the particular species involved. The degree to which the animal has been damaged by a stressful situation caused by nutrient or contaminant exposure may be determined, in many cases, by an "index" based on the quantities revealed by the analysis. Exposure to microorganisms may also be revealed using immunological techniques. All of these scientific procedures need to be quantified into a format suitable for management purposes. The ideal solution would be a model that, given toxicity inputs and environmental conditions, could provide a most probable stress index.

3b. Determine specific contaminants that compromise organism functioning to the degree that populations are affected.

Contaminants may affect populations in many ways. A major contaminant spill may result in the wholesale destruction of some benthic species from a particular area. In general, however, toxic effects of such spills tend to be less observable because they often interact with the physiology of the organism causing problems that are not immediately evident. For instance, shellfish such as oysters and scallops may have their reproductive capabilities reduced by exposure to certain chemicals. The result will be a reduced population in the future and a reduction in the value of the harvest available. Massive fish kills are also familiar to most coastal dwellers, as is the contamination of shellfish by organisms causing paralytic shellfish poisoning (PSP). The results of toxic exposure may also result in a population or species that, although suffering no ill-effect, becomes unfit for human consumption because of bioconcentration. Furthermore, external lesions and other deformities not only make fish less able to survive in the estuarine environment, resulting in reduced populations, but also reduce their desirability in the market place.

Again, knowledge of toxic effects on individuals or populations is of little use in itself except as a scientific exercise. To be effective, such information must be presented in a managerial context so that the funds expended may be recouped through effective decision-making processes. Once the toxic effects are well quantified, the information can be synthesized in a science-management context so that adequate risk assessments may be prepared when required.

3c. Determine the synergistic effects of a combination of contaminants on important populations.

For most of the toxic contaminants of greatest concern, we have at least some idea of the mortality dose-response relation for some common fish and invertebrate species. However, there is no guarantee that the most sensitive species have been studied, or that the effects of combinations of contaminants has been addressed. Further, much of our information concerning toxicity is derived from relatively short-term studies based on mortality. Our knowledge of long-term effects of exposure to toxics, especially sublethal chronic effects that may not directly lead to death, but do have major impacts on the ability of organisms to survive and reproduce, is much less extensive. In summary, our understanding of the cumulative effects of contaminants is inadequate.

Studies of bottom-dwelling organisms have indicated a decrease in species diversity and domination by pollution-tolerant species where sediments contain high concentrations of toxicants. Amphipods, which are a major dietary component of several species of estuarine and coastal fish, are among the forms that drop out. Some investigators have speculated that these ecological shifts could have adverse effects on fisheries production; however, such changes have not been demonstrated convincingly in estuarine field studies.

A combination of field and laboratory studies is required in order to determine cause-and-effect relationships between chemicals and biological effects. In field studies, statistical modeling could be used as a tool to investigate such relationships. Laboratory investigations will also be necessary to further understand relationships between biological perturbations and individual chemicals or groups of chemicals.

3d. Determine how the addition of contaminants affects estuarine trophic structure and dynamics.

In contrast to our understanding of the process of eutrophication, relatively little is known about the trophic implications of toxicant additions. Research to date has focused largely on correlative field observations or on laboratory studies of effects at the organism, tissue, and cellular levels. Relatively little work has focused on population- or community-level effects. However, the laboratory studies conducted to date have demonstrated that many pollutants have the potential to influence processes governing plankton growth (e.g., respiration and photosynthesis) and to produce acute or sublethal effects in individual planktonic organisms. Other experimental evidence suggests that exposure to chlorinated hydrocarbons or toxic metals such as copper and mercury may cause shifts in the dominant cell size of phytoplankton populations from larger to smaller forms. Since the basic trophic pathways in an estuary represent the foundation of the food chain and thus, the productivity of the area, mechanisms which adversely affect this structure are of vital interest to the estuarine manager. The coordination of ongoing field and laboratory efforts to identify factors that cause unnatural perturbations in the trophic system is required so that accurate prediction of such events is possible.

3e. Determine the threat to human health posed by the presence of toxics in seafood.

Research on selected toxic substances, such as mercury, has shown that bioconcentration of these materials through the food chain can have a devastating effect on the human population as was evidenced by the mercury contamination in the Minimata Bay incident. For most of the toxic materials that contaminate fish and shellfish, there is inadequate knowledge to assess the human health consequences of consumption of such contaminants. We need to establish the dose-response relationship between these contaminants and the pathologies they may cause in order to establish acceptable limits for occurrence of these materials in seafood from estuaries. Research should address both the circumstances and conditions that lead to the contamination of estuarine seafood at levels that threaten human health, and the relationship between the concentrations of contaminants found in the edible tissue of estuarine fish and shellfish and the threat to human health.

To address this problem, studies are needed concerning the specific factors that control accumulation of toxic contaminants in estuarine living resources as well as the factors that control the depuration, metabolic breakdown, and other means of eliminating these contaminants from such resources. Research is also needed to determine potential human exposure to contaminated resources under various conditions and the mechanisms that control such exposure. There is also a special need for further research to develop effective indicators of the level of risk to human health associated with living resources from a specific area or the hazards which may exist in specific areas used for recreational or other activities.

4. What are the effects of natural and human-caused nutrient loadings on ecosystem productivity?

NOAA research in areas such as the New York Bight and Chesapeake Bay have shown a positive relationship between human-caused nutrient loadings and ecosystem productivity. However, we are not presently able to reliably estimate the relations between specific concentrations of nutrients in estuaries and the actual effects they cause in estuarine ecosystems. Research efforts should focus on the following determinations:

4a. Determine the effects of eutrophication on critical life stages of important estuarine-dependent populations.

Euthrophication, or nutrient over-enrichment, has the effect of reducing the available oxygen supply in the water column. Such conditions are dangerous to benthic organisms of all types and can lead to a reduction in important estuarine resources species either through adult mortality or the disruption of complex metamorphic life stages. Aesthetically, eutrophication is responsible for extensive, unsightly "algae slicks" that affect the popularity of estuarine beaches when they wash ashore. As in all environmental problems, the cause and cure must be addressed and a prediction tool developed. In this way, managers may not always be able to prevent low dissolved oxygen events, but will be able to draw upon their knowledge of past incidents to accurately forecast these situations with a reasonable degree of accuracy.

4b. Determine how the addition of excessive nutrients affects trophic dynamics and community composition.

Considerable evidence suggests that the addition of biostimulants, especially organic carbons, phosphorus (in freshwater), and nitrogen (in marine systems) can lead to detrimental changes in aquatic food webs. Low levels of over-enrichment may enhance primary production and increase the biomass of desirable organisms; however, sustained, high-volume additions of organic matter or nutrients generally produce undesirable shifts in community structure and environmental quality. As a result of associated changes in trophic dynamics, the accumulation of pollutants in sediments, and the recycling of excess carbon and nutrients, effects may continue after the sources of pollution are removed. Research efforts in this area should focus on acquiring a better understanding of the factors that determine the trophic rates and pathways. Under such conditions, the roles and dynamics of the microbial components are of special interest. Also of concern to both environmental managers and scientists are the incremental and cumulative effects of biostimulants, and the reversibility of such effects.

Evidence also suggests that fishing or stocking practices can alter the complexion of predator species and, in turn, result in fundamental changes in estuarine food web dynamics. By-and-large, such observations stem from studies of grossly polluted systems or systems whose fauna have been significantly altered as a result of fisheries management practices. Even in the most intensely studied estuaries, ecosystems response to contaminants generally is understood on a qualitative rather than a quantitative level. Models may exist that permit retrospective analyses, but rarely is prediction of contaminant response possible.

5. What are the effects of pathogens on estuarine resources?

Estuarine research involving the sources and effects of marine pathogens should focus on the determination of the mechanisms through which pathogens affect populations of important living resources.

C. Synthesis and Prediction

1. What conceptual approaches (models) can be used to relate contamination of broad areas of estuarine habitats to population changes for representative species of concern?

There is a need to refine conceptual approaches that have been developed recently by NOAA scientists to relate pollution to effects on populations of important living marine resources -- primarily those which are estuarine-dependent. Our objective is to develop the capability to predict population changes (losses in particular) that can be expected to result from land-use and effluent discharge practices. In order to make successful population predictions, field-tested models are required that can accurately simulate actual conditions. Because these models may have hundreds of variables, the construction of the initial algorithm is usually the most difficult and crucial aspect of any such undertaking. It is essential, then, that those tasked with the collection of estuarine information work closely with the management cadre so that as many "gaps" as possible are filled and our understanding is as thorough as possible. Only in this way will our forecasting gain a reputation for reliability. We will then be able to advise other agencies on the long-term effects of their policies on estuarine-dependent populations of living marine resources.

2. How can information transfer and predictive capabilities be improved to better inform the public on the consequences of fisheries contamination on harvest and marketability?

The public usually becomes aware of adverse impacts on a particular fishery when the price per pound of a desirable food species begins to increase in the market place. This situation may be the result of increased mortality because of either the introduction of toxic materials into the environment or unwise overfishing. In the former case, however, the impact may be much wider than the average person realizes. In many cases, the decline of a fishery results in lost livelihood and unemployment as occurred in the Chesapeake Bay oyster and scallop fisheries. As another example, a few years ago there was evidence that bluefish in the New York Bight were contaminated by levels of PCBs that exceeded the Food and Drug Administration action limit. A report was published showing that both the retail fish markets and sportfishing industry were adversely affected. Not only did the demand for bluefish decrease, but the sales of items associated with the offshore activity (bait, diesel fuel, tackle, fees to park and to use public toll roads, etc.) also declined.

It is clear that there are real and perceived contaminant effects on the economy of a fishery. The public is increasingly aware of insidious threats to human health and tends to react aggressively against any situation that it perceives to be harmful. It is therefore extremely important that NOAA ensure that its reporting on contaminate affects is accurate, timely, and concise.

In many cases, it is not possible to prevent red tides, fish kills, or other catastrophic marine events. However, sufficient support information now exists to permit the timely prediction of such problems and the rapid dissemination of health bulletins. If accurate and timely information on these events can be developed, NOAA and other Federal agencies such as EPA and the U.S. Public Health Service may effectively reduce economic losses and threats to human health. Models have been developed that use relatively simple surrogate variables to predict the presence of pathogenic amoebae in oceanic sediments. Other such management devices need to be developed so that assessments may be rapidly generated as required. As previously noted, only cooperation between the field investigator, manager, and modeler can result in the finely tuned simulation tools necessary for successful decision-making.

Chapter IV

HABITAT

OBJECTIVE

To understand the importance of habitat and to predict the effects of habitat loss or physical alteration on populations of living resources.

PRIORITY QUESTIONS

A. Observation and Assessment

1. What are the critical fisheries habitats for food, cover, spawning, nursery areas, migration?

2. What are the existing distributions, rates of change, and documented causes of loss for estuarine habitat types?

3. What is the extent and status of past mitigation actions?

B. Research

1. What is the relative functional importance of primary estuarine habitat types for important living marine resources?

2. What is the natural variability in habitat functions, and how do perturbations and long-term changes in environmental factors affect habitat functions?

3. What are the effects of cumulative habitat loss on fisheries productivity and economic value, both regionally and nationally?

4. Does habitat restoration through mitigation and enhancement compensate functionally for habitat loss or alteration?

C. Synthesis and Prediction

1. What conceptual approaches (models) can be developed and used to assess and predict the effects of cumulative habitat loss on regional fisheries production?

2. What is the significance of the contribution of estuarine productivity, both primary and secondary, to offshore ecosystem productivity (i.e., are offshore stocks dependent upon estuarine productivity)?

CHAPTER IV

HABITAT

I. OBJECTIVE

To understand the importance of habitat and to predict the effects of habitat loss or physical alteration on populations of living resources.

II. PROBLEM DEFINITION

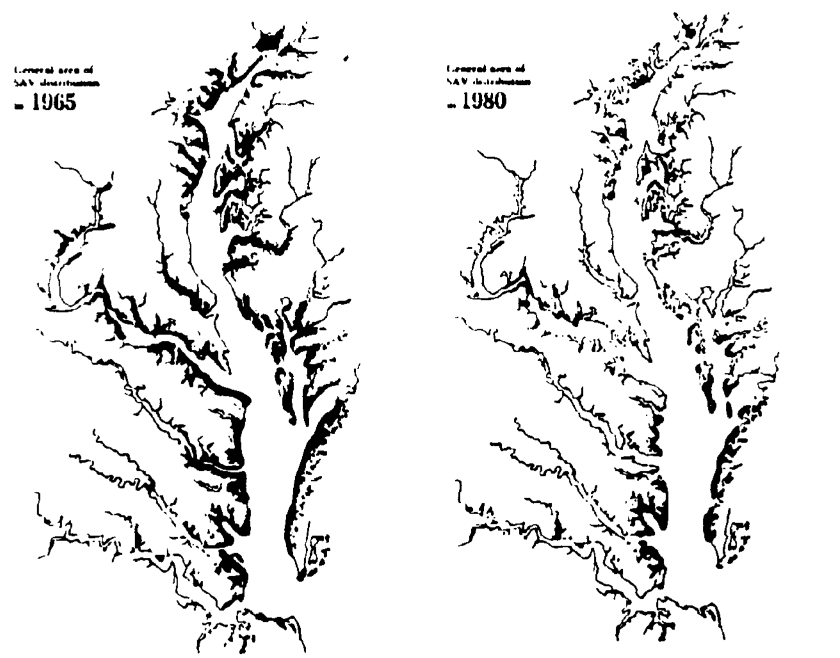
Loss of important estuarine habitat is a national-level concern, especially in view of the fact that 70 percent of the U.S. commercial fisheries catch is dependent on these areas for spawning, nursery, and feeding. Estuarine areas are being degraded and wetlands that provide fishery habitat are rapidly disappearing in many areas of the country. In 1780, what is now the continental United States had an estimated 11 million acres of coastal wetland -- by 1978 only 5.7 million acres remained. In Louisiana, which contains roughly half the Nation's coastal wetlands, losses prior to 1956 were estimated to be 16.5 square miles/year. The most recent data indicate this rate is now 60 square miles/year (Figure 11). Connecticut has lost over 66 percent of its coastal marsh, while California's San Francisco Bay wetlands have been reduced 75 percent (from 300 to 75 square miles). In Chesapeake Bay, submerged aquatic vegetation decreased drastically between 1965 and 1980 (Figure 12), simultaneously with declines of several estuarine-dependent species such as American shad, striped bass, white perch, alewife, and blueback herring. Physical and chemical-related processes associated with human activities, as well as natural causes, contributed to these losses. Current estimates that approximately 75 percent of the U.S. population will live in coastal states by 1990 suggest that even greater losses will occur over time, as the competition for limited space and resources increases.

The loss or modification of ecologically important habitats affects estuarine productivity. Because suitable estuarine habitat is required by a significant number of marine organisms for spawning, growth, and survival, the biological productivity of an estuarine/coastal system declines as the quality and quantity of habitat decreases. Furthermore, productivity will continue to decline until habitat loss is reversed. This process has been documented in scientific studies that demonstrate strong correlations between deteriorating habitat and fishery declines (e.g., loss in productivity and yield of a species). However, the combination of events that control

LOUISIANA COASTAL MARSH LOSS

(Source: US Fish and Wildlife Service, National Wetlands Research Center)

FIGURE 11



Decline in submerged aquatic vegetation (SAV) from 1965 to 1980 in the Chesapeake Bay

(Source: US Environmental Protection Agency. 1983)

FIGURE 12

productivity is poorly understood. Consequently, the effects of human activities on fisheries production versus natural processes affecting habitat availabilities are difficult to evaluate. Therefore, the agencies responsible for coastal management are either forced into a reactive posture with regard to wetlands degradation and adjacent upland modification, or must base preventive programs on less than complete scientific information. Without better quantification of the relationships between productivity and the quality and quantity of habitat, public decisions on land-use will continue to be made on the basis of supposition rather than established fact regarding the effects of habitat alteration on estuarine and coastal productivity.

Our ability to assess the immediate and long-term effects of society's activities on fisheries habitat will depend on our knowledge of habitat functions, the quantity of habitat loss, and the rate of recovery of damaged systems. Resource managers must have this information to predict what losses of living marine resources would occur in the event of habitat alterations. Unfortunately, in most locales we have a poor understanding of the functional value of estuarine habitats, quality of various wetland types, or their rate of loss. Additionally, we have not developed effective mitigation and enhancement approaches to ameliorate habitat loss through regulatory programs. The effectiveness of current mitigative measures in replacing lost habitat is not yet proven, and information is lacking on the rate of successful replacement or enhancement. In most instances, we do not even know whether previous habitat mitigation attempts have been successful. This knowledge is critical for effective management of habitats through the permit-mitigation process.

To minimize habitat degradation, we must understand the role and value of different habitats and the best techniques for mitigating or restoring damaged habitats. We must also inventory the destruction of wetland habitats and modification of adjacent upland areas, monitor habitat changes through the regulatory program, and ensure that our management and administrative processes effectively translate this information to the decision-making process.

III. STRATEGY

NOAA's strategy for habitats is: 1) to collect and assess information on habitats that are critical to fisheries populations of concern; 2) conduct research on the relationship of estuarine habitat to productivity of fisheries of concern; and 3) to determine the distribution and rate of loss of estuarine habitat types that are important to living marine resources. This will be accomplished by collecting and evaluating existing data;

collecting new information for resource dependence on estuarine ecosystems from field studies; and collecting data from remotely sensed imagery to map important habitats.

A. Observation and Assessment

The assessment of information is an important element of the habitat component of NOAA's efforts in estuaries. Questions to be addressed are:

1. What are the critical fisheries habitats for food, cover, spawning, nursery areas, and migration?

If we are to wisely manage estuarine-dependent fishery populations, we must know which habitats are critical to their continued survival. We know a great deal about a number of species' life history and general distribution, particularly in their adult life stages; however, we know very little about the early life history of most species of concern. Generally, we do not know where these species spawn or which areas are important nursery and feeding areas. The characteristics of such areas must be determined for species of concern in order to protect them from unwise use or modification. Priority areas of consideration include:

1a. Determine the seasonal distribution (vertical and horizontal) of each life-history stage of important species and the major areas of concentration.

1b. Determine the substrate type, water quality parameters, food availability, etc. that are necessary for successful growth, maturation, reproduction, and survival.

2. What are the existing distributions, rates of change, and documented causes of loss for estuarine habitat types?

Coastal marshes, aquatic macrophytic beds, and tidal flats serve as nurseries for many commercially important fish and shellfish, and provide a significant amount of the organic matter processed by nearshore marine ecosystems. There is concern that much of this highly productive coastal habitat is disappearing because of both direct destruction (dredging or filling) and indirect effects of pollution, herbicides, fertilizers, etc. These losses have affected, and will continue to affect, the coastal fisheries, but it is difficult to document them systematically. Part of the reason is that no standard documentation of habitat changes exists among the coastal states. Coastal wetlands mapping differs from one state to the next making it impossible to compare losses or modifications of wetland coverage and to relate these to potential impacts on fisheries, particularly those that cross state boundaries.

Very little information on the disappearance of coastal habitats on a large scale is available. To address this lack of information, measurement of change in coastal habitat areas, location and health must be undertaken. The only technology that has potential for performing all of these tasks within reasonable cost and time constraints is digital remote sensing by satellites. A regional and national inventory of major habitat types and their rate of loss or gain is required. Finally, NOAA should develop a wetlands data and information management system to monitor cumulative impacts. Priority areas of consideration include:

2a. Determine the existing quantity and distribution of estuarine and coastal habitat types by state, county, and watershed.

The coastal and estuarine wetlands of the United States should be assessed every five to ten years and monitored annually in regions of significant change. Remotely-sensed data from the Multispectial Scanner (MSS) and Thematic Mapper (TM) sensors, as well as "ground-truthing" by wetlands and estuarine ecologists, will be required. An operational protocol capable of handling any format of MSS or TM data must be established for all U.S. regions. The protocol must provide a uniform basis for habitat classification, and thereby allow intercomparison of two or more images, regions, or times. The protocol would also include substantial "ground-truthing" procedures for validation of satellite measurements. The establishment of an operational classification system based on the protocol (including software and algorithm development) would be a one-time cost, and once established would be shared by all users.

2b. Determine the historical rate of change of estuarine and coastal habitats by region, state, county, and watershed.

A uniform documentation of vegetational coverage and change should be completed. The derived products would consist of maps and tables listing areal coverage (hectares) by state, county, and watershed for each classified type.

2c. Determine the documented causes for the changes (in particular, losses) of estuarine and coastal habitats.

NOAA should develop a system to account for nationwide coastal habitat change caused by Federal projects, permits, and other authorizations, as well as natural causes, which together result in habitat loss or degradation. Remotely sensed data, as well as knowledge of Federal agency projects and approvals of projects, will be required to assess the loss rates attributable to legal, permitted, and illegal activities. These data must be related to the historical data base on wetland acreages. At present, state and Federal agencies estimate losses based only on permitted activities under the Corps' jurisdiction. However, we have no measure of what is actually being lost, as there is no follow-up to evaluate permitted projects, nor do we account for other projects (legal and illegal) or natural change.

The creation of a standardized computer-based accounting system would assist in the collection of such information. There must be a common, uniform reporting basis, not solely for habitat types, but also on causes of habitat loss (e.g., dredge and fill, navigation channels, marinas, housing developments) and on estimates of acreages subject to degradation or deterioration from contaminants. Efforts are also necessary to determine wetland gains and losses that are attributable to natural causes. These data need to be compiled and updated yearly on regional, state, county, and watershed bases so that managers and scientists can direct their management efforts and research appropriately. A wetlands and information management system should be established to incorporate these data.

3. What is the extent and status of past mitigation actions?

There is a great deal of pressure to develop mitigation and enhancement approaches to ameliorate habitat loss through the regulatory process. As discussed earlier, the effectiveness of mitigative measures in compensating for lost habitat is poorly known, as is information on the rate of successful replacement or enhancement. In most instances, we do not even know if the actions were successful. This knowledge is critical for effective management of habitats through the permit-mitigation process. NOAA must continue to stress that there are no tradeoffs for the removal or destruction of natural habitat, and that mitigation should be considered to minimize adverse impacts only when projects are deemed to be in the public interest. A survey of past mitigation, compensation, and restoration attempts to determine their success would help to measure the utility of such management approaches in compensating for lost functional values and resource production.

B. <u>Research</u>

1. What is the relative functional importance of primary estuarine habitat types for important living marine resources?

To address this question, research in both spawning and nursery areas must be conducted. Research on early life-history must identify biological, physical, and chemical characteristics of primary spawning areas for selected estuarine-dependent species; determine the relative importance of factors which affect survival of eggs and larvae; determine the transport mechanisms that deliver larvae to estuarine nursery areas; and determine the importance of offshore intrusions of nutrient-rich water to support the feeding of early life-history stages. Habitats that need to be addressed include high and low marshes, seagrass meadows, mangroves, intertidal, and subtidal unvegetated habitats. Priority areas of concern include:

1a. Determine the relative importance of the quality of nursery area habitat as it affects abundance, distribution, growth and survival of juvenile living marine resources including an assessment of conditions limiting food supply, relative importance of predation, and relative mortality rates.

Research needs to be conducted on the relative importance of the quality of nursery areas as they affect abundance, distribution, growth, and survival of juvenile living marine resources. Qualitative studies should include those conditions limiting food supply, the relative importance of predation, and relative mortality rates.

1b. Determine the biological, physical, and chemical characteristics of primary spawning and nursery areas for selected species.

Qualities of the nursery area that must be considered include: plant composition and density; sediment type, composition and organic content; and hydrologic conditions. All of these factors influence species composition, abundance and interactions.

1c. Determine the factors that affect survival of eggs and larvae.

Once larvae have entered estuaries, survival is dependent on the size, accessibility, and type of habitat available, as well as postlarva naturally occurring physical, chemical and biological processes. Research topics should include habitat utilization in terms of the life-history of the organism. For instance, species-specific settlement of postlarvae into different habitats and seasonal use of habitats for purposes of feeding, refuge from predation, and spawning should be studied. Research should also be directed toward resource use, predator use, and predator-prey interaction and factors that control them.

2. What is the natural variability in habitat functions, and how do perturbations in environmental factors affect habitat functions?

Research needs to be conducted to determine how the variability of wetlands to open water and the amount of interface between the two affect secondary production, the exchange of nutrients and detritus, and exploitation of the habitat. The influence of changing water levels due to subsidence and/or sea level rise on habitat functions that provide living marine resources with space, food and/or protection has not been adequately addressed. Research is also needed on how long-term environmental patterns are reflected in variability among species abundances and how long-term changes in geomorphology of estuaries influence migration routes of living marine resources. Attention also should be given to whether recruitment patterns to estuaries are related to variability in morphological features among estuaries.

3. What are the effects of cumulative habitat loss on fisheries productivity and their economic value, both regionally and nationally?

Our ability to assess immediate and long-term effects of habitat alteration will depend on our knowledge of habitat functions, both spatially and temporally, the quantity of habitat loss, and the rate of recovery of damaged systems. Resource managers must have this information to predict the losses of living marine resources that would occur in the event of habitat alterations. Specifically, research is needed to address the impacts of perturbations on fishery habitats, including migration pathways. What are the impacts of altered freshwater inflows on vegetation patterns and resulting changes in functional processes? What are the impacts of construction of shoreline structures and what are their relative habitat values? What is the cost to living marine resources of re-impounding wetlands? A major problem exists and will continue to exist pertaining to dredging and the need to find disposal sites. Open water disposal of dredged material continues to be an important issue and increasingly affects estuarine and coastal habitats on a regional basis. The value of the habitat that is lost to disposal activity is rarely known. These are just a few of the information voids that exist and need to be addressed regarding the well-being of living marine resources. Priority areas of concern include:

3a. Determine population effects due to regional wetland losses for important species.

For species that are dependent upon particular estuarine habitat types, we need to assess the consequences of habitat loss or modification throughout the species' range. This will require considerable life-history and population information and the development of suitable conceptual approaches to relate mortality to habitat loss within the natural variability that is known to exist for all populations.

3b. Determine the effects of changes in freshwater inflow on major estuarine ecosystems (e.g., San Francisco Bay, Columbia River, Pamlico-Albemarle Sound, Texas coastal estuaries) resulting from changed vegetation patterns and changed functional processes.

Changes in estuarine habitats (e.g. marsh loss due to decreased freshwater input) have profound implications for resources dependent upon such areas. For selected areas known to have been adversely affected by either too little or too much freshwater inflow, we need to quantitatively assess the effects such changes have had on living marine resources and ecosystem functioning.

4. Does habitat restoration through mitigation and enhancement compensate functionally for habitat loss or alteration?

We do not know whether re-created habitat that was ostensibly provided to compensate for lost habitat actually replaces the functional value of the lost habitat and thus compensates for lost resource productivity. Habitat mitigation through the restoration and enhancement of damaged habitat, and the generation of new or replacement habitat is used by regulatory agencies such as the Corps of Engineers to ameliorate losses of submerged and emergent wetlands and subtidal shallow-water habitat critical to the growth and survival of living marine resources. Several techniques have been developed to propagate marshes, mangroves, and seagrass meadows and to create shallow habitats for estuarine and coastal species. Although this mitigation concept may be an effective way to reduce the rate of habitat loss, we do not know the extent to which these approaches are successful or whether such restoration adequately compensates for the loss of natural habitat.

We have been able to document the proper way to create replacement habitat of similar appearance to that which was lost. We need to conduct research to determine whether all the original functional values are eventually restored as well. The science of mitigation is still imperfect, and there is little basis upon which to judge whether mitigated habitats (which may take many years to develop, if they do at all) support estuarine production to an extent similar to natural habitat. Federal and state agencies have attempted mitigation, but have not evaluated the results in terms of success or failure. It is therefore timely for a research strategy to address priority topics in the following areas:

4a. Determine whether functional values of mitigated habitat compare to natural values, at what rate does the replacement of functional process take place, and what is the interim living marine resource loss.

To address success and replacement functions for mitigation requires long-term evaluation. This can be done by studying mitigation attempts that were initiated at different times. Evaluation techniques used to determine relative habitat value should also be applied to mitigated habitat over a long period of time. In addition, research efforts are needed to determine relative habitat value, including sediment development, plant cover, microbial and detrital development, faunal utilization, and trophic linkages. The strength in this approach is that where reliable experimental designs can be established, there is the potential for determining quantitative measures of failure and success, and conclusions rather than inferences can be drawn as to future mitigation procedures that could be employed routinely.

4b. Assess and determine the most appropriate methodologies to contribute to the success of mitigation actions.

Although technologies exist to propagate marsh, seagrass, and mangroves, we do not know the appropriate ratio of restored acreage to that acreage needed to offset the loss of functional characteristics upon which living marine resources are dependent. Nor is there sufficient information available on population density. Under most circumstances, uniform coverage marshes are planted, although recent research strongly suggests that reticulated marshes may provide greater access to the marsh for fishery organisms. Experiments should be conducted on the use of dredged material to restore shallow water habitats important to fishery species. Within this question is the need to conduct research on whether in-kind wetland habitat replacement is necessary or can replacement be made with other kinds of plant species? The resolution of this question is a function of available information on the relative value of different estuarine habitats and is vital to effective habitat conservation. In addition, the use of mitigation banking as a method to compensate for habitat lost must be evaluated, as the viability of this approach is in question.

C. Synthesis and Prediction

1. What conceptual approaches (models) can be developed and used to assess and predict the effects of cumulative habitat loss on regional fisheries production?

Our objective is to develop the capability to predict future population change (i.e., losses) that would be expected to occur with a continuation of current agency policies that now result in significant cumulative habitat loss throughout the range of important marine species. For example, wetland losses may significantly affect shrimp and menhaden populations. We hope to be able to advise agencies that are responsible for such policies on the desirability of changing those that are detrimental to habitats critical to the continued existence of valuable living marine resources.

Research is needed on developing conceptual approach models that relate changes in primary habitat types such as wetlands to the productivity of selected living marine resources. This will primarily involve the collection of basic life-history and population data for selected species. Once this information is available, conceptual approaches that utilize existing population dynamics models will need to be developed. Later, the models can incorporate sensitivity analyses on different aspects to estimate potential ranges of impact of various types and degrees of habitat alterations on living marine resources. Additionally, research should be directed at developing population models that allow estimation of habitat values to different life stages, recruitment among populations, and different potential sources of natural, pollutant, and fishing-induced mortality. Priority areas of concern include:

1a. Develop population models and the biological data needed to operate the model that allow estimation of habitat to different life stages, recruitment among populations, and different potential sources of mortality due to habitat alteration.

Existing population dynamics models need to be modified to incorporate factors pertinent to early life-history survival and reproduction for the species of concern. Such models are now under consideration; additional work should be done to relate population dynamics to habitat change. Moreover, considerable data will be required to operate the models, if they can be developed. We need to know a considerable amount about a species population's characteristics in order to separate mortality caused by habitat alteration from natural variability in populations.

1b. Conduct sensitivity analyses on aspects of the models to estimate potential ranges of impact of various degrees and kinds of habitat alterations.

If conceptual models can be satisfactorily developed for selected species and suitable data are available, a sensitivity analysis can be conducted to refine estimates of mortality attributable to habitat loss over broad areas of the species range.

1c. Determine the relationships between loss of habitat and change (decline) in fishery resources.

This task involves a synthesis of findings from research on estuarine coupling and from related estuarine investigations of habitat issues and pollution effects. Achieving such a synthesis would be a major step toward addressing the central estuarine-related management concern: Do human activities in estuaries adversely affect fisheries yield, and if so, how might they be avoided or minimized? A synthesis of the estuarine coupling studies should be built around answers to questions such as the following: What is the relative importance of major habitat types to fishery production? What are the implications to fishery production of altering the quantity or quality of estuarine habitats? Can secondary production be protected or improved by managing for specific levels of primary production? Is control of primary producers by predators a major factor in estuaries with detritus-based food webs?

2. What is the significance of the contribution of estuarine productivity (primary and secondary) to offshore ecosystems productivity (i.e., are offshore stocks dependent upon estuarine productivity)?

Because many inshore-dependent fish species are migratory and thus are harvested away from nursery areas, control of the harvest to ensure optimum utilization of a fishery resource requires an understanding of the origin of the stocks contributing to that fishery, knowledge of the inshore waters from which they originate, and the migratory patterns of the species. Perhaps of equal importance is the contribution to offshore ecosystems of food in the form of both detritus and animals that were either produced or nourished in estuaries. Recent evidence suggests that offshore stocks in the Southeast cannot be supported by the plankton productivity alone from offshore waters. In fact, it may be that estuarine-derived detritus is providing the critical balance. Detritus, in turn, may be the primary nourishment of the vast populations of menhaden, which are the principal forage species for many important recreational and commercial species found predominantly offshore. Offshore stocks of valuable living resources may thus be dependent both directly and indirectly on the productivity of estuaries.

Tasks to be accomplished to address this question are: 1) determine the significance of the flux of oxidizable organic matter from estuarine to shelf ecosystems and how this varies from one estuary to another; 2) determine the significance of the estuarine portion of the life cycle to the entire life cycle of selected estuarine-dependent species; 3) determine how significant estuarine-dependent species are as prey for coastal and offshore species; and 4) determine how significant estuarine-dependent species are as predators of coastal species.

Chapter V

LIVING RESOURCES

OBJECTIVE

To understand the causes of living resource declines and to predict the effects of human activities on populations of important species.

A. Observation and Assessment

1. What are the historical trends of estuarine-dependent stocks?

2. What is the present distribution, abundance, and health of estuarine-dependent fish stocks?

3. What is the economic value of fisheries?

B. Research

1. What are the key trophic pathways in estuarine ecosystems and how does the flux of essential nutrients, carbon compounds, and energy through these systems influence fisheries productivity?

2. How are trophic pathways affected by natural events and human activities?

3. What are the relative effects of fishing, pollution, and natural mortality on fishery population dynamics?

4. What are the ecosystem impacts of harvesting and stocking fishery resources on food web dynamics and predator-prey interactions?

C. Synthesis and Prediction

1. What conceptual approaches (models) can be developed and used to relate fishing mortality to that caused by habitat degradation and natural factors?

2. What are the cumulative effects of human activities on important fishery populations?

3. What are the trade-offs (i.e., economic, ecological, and social) for various national or regional estuarine and coastal policy options?

4. What are the predicted consequences of proposed or existing fishery management regulations?

5. What are the priority estuaries for NOAA's scientific attention?

CHAPTER V

LIVING RESOURCES

I. OBJECTIVE STATEMENT

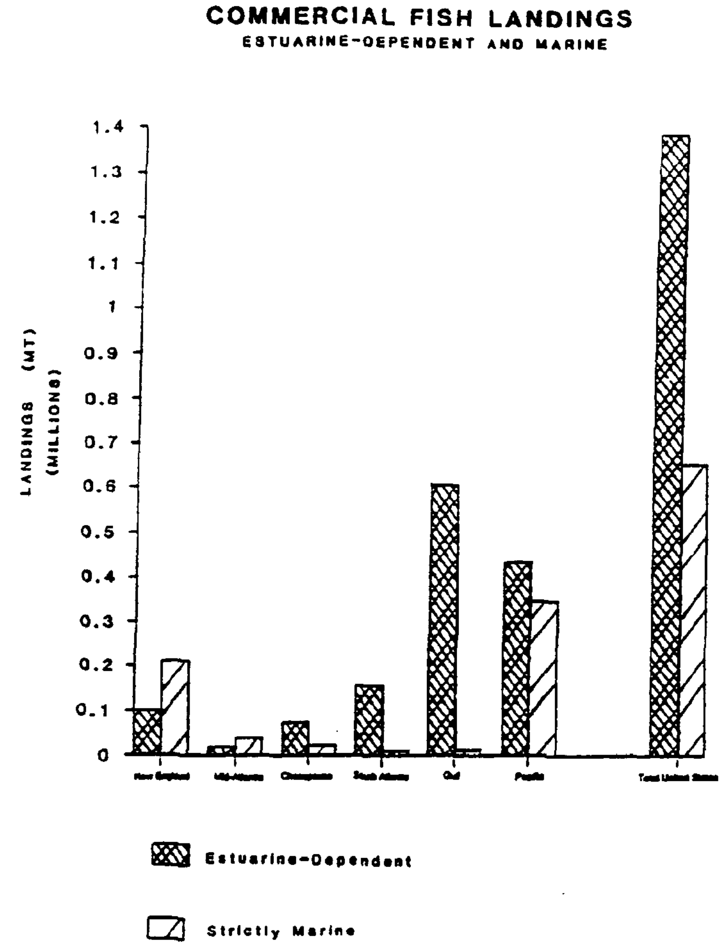
To understand the causes of living resource declines and to predict the effects of human activities on populations of important species.

II. PROBLEM DEFINITION

The vast majority of our highly-valued living marine resources are critically dependent upon estuarine environments. In fact, estuarine-dependent species comprise approximately seventy percent of the U.S. commercial catch (see Figure 13). This proportion is much higher in the South Atlantic (94 percent) and Gulf of Mexico (98 percent). Dramatic declines in several of our commercially and recreationally important fisheries are shown in Figure 14. These declines have been attributed to overfishing, loss of habitat, pollution, environmental alteration, disease, and natural variability of the stock. Most of these stocks have probably declined because of interactive or additive effects of many of these factors. Thus, effective fisheries management requires an understanding of these factors and trophic interactions.

To a great extent, previous research on trophic interactions in estuaries has been dominated by descriptive and qualitative studies. Research emphasis should be shifted from characterizing estuarine food webs through the use of gut content analyses and laboratory feeding studies to the dynamics of trophic interactions. Also important is research on microbial and benthic processes, especially as they relate to detrital feeding and the recycling of nutrients and carbon. Deciphering the influence of natural versus human-associated factors on the coupling of primary and secondary production is also of concern, as is obtaining an improved understanding of the nutrient, carbon, and energy fluxes through estuarine systems.

We are chiefly concerned with the pathways in ecosystems that lead to fish productivity and how human activity alters that productivity. Research is needed to provide knowledge of the key trophic pathways and the factors that affect energy flow in the estuarine ecosystem. This understanding of ecological processes must then be combined with information on the current health, distribution, and abundances of ecologically important estuarine organisms. With an understanding of the ecological linkages and information on the current status of fishery stocks, managers of fisheries and habitat resources will be better able to manage estuarine-dependent living marine resources that might otherwise be threatened by overfishing and/or habitat degradation.



(Source: NOAA/NMFS, Fisheries Statistics Division, 1987)

FIGURE 13

III. STRATEGY

The strategy for meeting these needs consists of: 1) observation and assessment of fishery stocks; 2) research on ecosystem dynamics, natural and human effects on trophic pathways, fishery population dynamics, and food web dynamics; and 3) synthesis and prediction to relate fishing mortality and habitat degradation, and the effects of human activities on fishery populations. Additional efforts will include analysis of policy options for estuarine resource management, and establishing priority estuaries for scientific attention.

DECLINES IN LANDINGS FOR ESTUARINE DEPENDENT SPECIES
(Source: NOAA/NMFS, Fisheries Statistics Division, 1987)

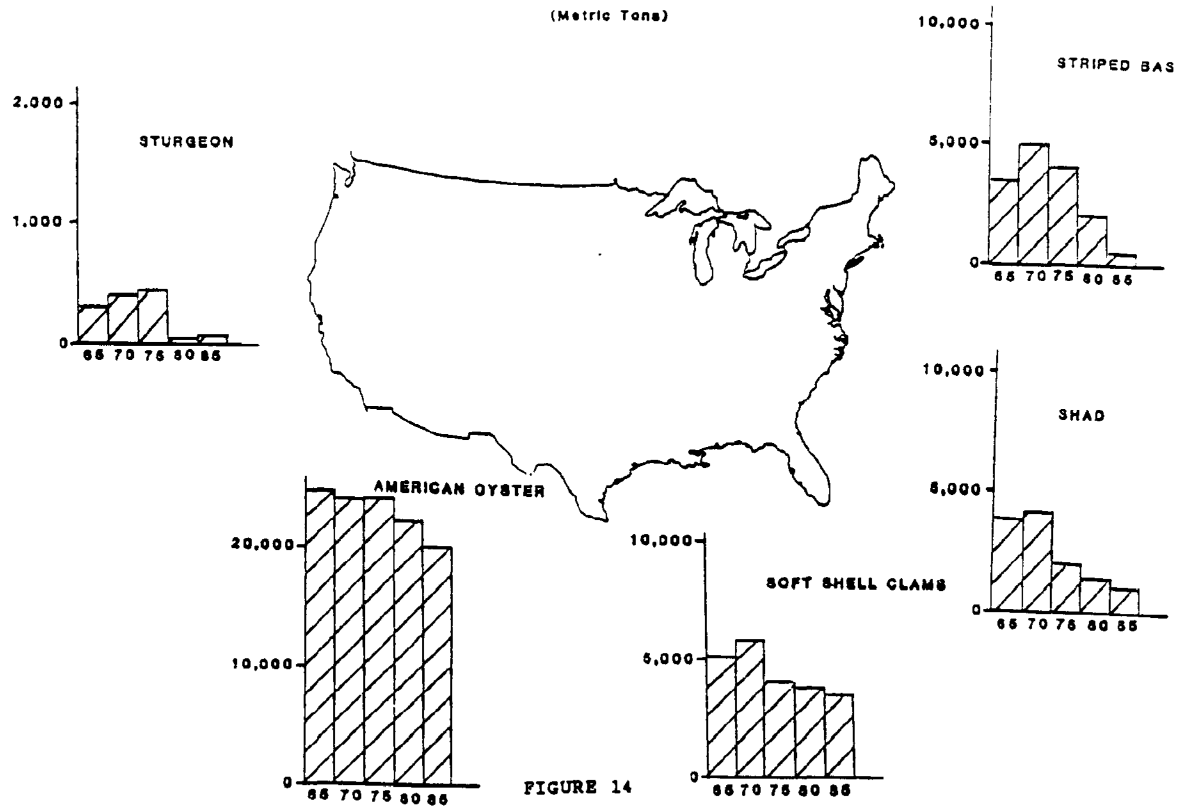


FIGURE 14

A. Observation and Assessment

1. What are the historical trends of estuarine-dependent stocks?

Historical trend information for stocks of estuarine-dependent species of recreational, commercial, and ecological value would provide a basis for assessing relationships with human development trends in coastal areas. Such information is currently developed for selected stocks by reconstructing population data from historical fishing catch and effort data, where possible. Priority areas related to this problem are: 1) assemble and evaluate the quality of available data; 2) develop methods to relate dissimilar data from separate collecting programs to provide a common national data set; and 3) reconstruct population estimates from existing data on catch/effort or other relatable data set (e.g., juvenile indices, landing data) for primary estuarine-dependent species of fish and shellfish for selected coastal regions.

2. What is the present distribution, abundance, and health of estuarine-dependent fish stocks?

Because many estuarine-dependent species are migratory, and thus are harvested away from nursery areas, it is difficult to link quality of the nursery areas to the abundance and health of these species. Optimum utilization of a fishery resource requires an understanding of the origin of the stocks contributing to that fishery, knowledge of their habitat requirements, the "health" of stocks, and the migratory patterns of the species. It is also important to know the range and extent of estuarine-dependent stock within coastal fisheries. We have developed considerable knowledge of the biology and population dynamics of a number of important species, particularly those found offshore. However, we know very little of the early life-history of many estuarine-dependent species, although this is critical information required for management of such stocks' habitat. To analyze the effects and interactions of contaminant and pathogen exposure and fishing on yields of inshore-dependent fishery resources, we need to understand the interaction among natural population dynamics, pollution-related mortality, and fishing mortality. The interactions between human-induced and natural stresses (including infectious disease agents) and how fishery resources react to cumulative stress must also be understood and evaluated. Another important task is to coordinate the state-level collection of data on living marine resources to determine distribution, population dynamics, health, and abundance. Information is needed on species' distribution, migration, movement patterns, stock definition, abundance, residence time, and seasonality of use of estuarine habitat by life stage (including age and size structure). Information on the distribution and prevalence of disease and other fish disorders is also essential to evaluating health of the stock.

3. What is the economic value of fisheries?

If habitats important to recreational and commercial species are to be properly weighed in public policy decision-making, the value of the living resources that are supported by such habitats must be recognized. Fishery valuation in the past has traditionally not considered all present and future values of such species to society. Innovative approaches must be developed and utilized.

Potential tasks to address this question include: 1) obtain and evaluate population data regionally for important species of fish and shellfish; 2) evaluate methodologies for projecting values of fisheries to society taking into account their full range of influence on our quality of life; 3) select appropriate methodologies for species of primary interest and develop estimates of value, regionally; and 4) hold a national workshop to evaluate results.

B. Research

1. What are the key trophic pathways in estuarine ecosystems, and how does the flux of essential nutrients, carbon compounds, and energy through these systems influence fisheries productivity?

Estuaries are dynamic, heterogeneous marine environments. Specific environmental conditions reflect not only the local physio-chemical setting, but also inputs from upstream, upland, and oceanic environments, including water, organisms, and substances ranging from suspended sediments and detritus through nutrients and toxic substances. All of these are imposed on resident microbial, floral, and faunal communities. Much of the scientific attention that has been paid to estuaries focuses on characterizing the structure of such communities and the temporal and spatial variability of the systems that support them. Estuarine assemblages may take on many forms; however, it is unlikely that all are of equal value for the support of fishery resources. For example, the role and relative importance of seagrass-dominated estuaries along the Mid-Atlantic may well be different from those of mangrove dominated estuaries along the Gulf Coast, or mudflat dominated estuaries in New England. For further progress to be made, emphasis must be placed on understanding the trophic linkages between structural elements in estuarine food webs. This includes identifying those linkages that are of greatest consequence to fishery production and the factors that control the complexity and composition of trophic linkages. Better understanding is also required of the rates at which materials cycle through estuarine food webs and the factors governing trophic processes and products. Priority areas related to this problem are:

1a. Determine the major sources of food (fixed carbon) in selected estuarine and coastal ecosystems.

We need an understanding of the relative importance of major sources of organic carbon in estuarine ecosystems. New techniques and recent studies have greatly enhanced our understanding of the overall structure of estuarine food webs and the relative contributions of major groups of estuarine primary producers -- rooted aquatic vegetation, terrestrial vegetation, phytoplankton, benthic algae, and estuarine microbes. For example, new techniques such as stable isotope analyses have enabled scientists to go beyond traditional stomach content examinations and laboratory feeding experiments in evaluating the relative importance of various sources of fixed carbon for the support of estuarine secondary (fishery) production. Also, recent studies suggest that bacteria may be key factors in disruptive events such as episodes of hypoxia/anoxia and blooms of nuisance algae, as a result of their role in carbon and nutrient regeneration. Attention must now be focused on variations in primary productivity and their implications for trophic dynamics. Within individual estuaries, what controls autotrophic production? How do the relative contributions of autotrophic groups vary over space and time? What is the trophic significance of such shifts? What are the food chain effects of aperiodic variations associated with storm events and ecological succession?

1b. Determine the linkages between plant production and harvestable fishery species.

It is now possible to describe major trophic pathways in well-studied estuarine systems and to develop models of the overall flux of carbon, nutrients, and energy. However, it is difficult to relate such calculations to fishery production. Generally, detailed information is lacking about food webs that support commercially or recreationally important estuarine finfish and shellfish. A limited number of efforts are underway to define more precisely the distributions and habitat requirements of estuarine species. These need to be expanded, with emphasis placed on the feeding habits and nutritional requirements of early life-history stages as well as adults.

1c. Determine the efficiency and plasticity of pathways linking primary production and fishery species.

We need to know whether changes in species that comprise the food chain will have an adverse effect on species of concern. Among the most contentious issues in studies of the coupling of estuarine primary and secondary production is the relationship between the quantity and quality of available food items and fisheries productivity. Research indicates that all other things being equal, estuaries with the highest quality foods should produce the highest fishery yields. In this regard, more detailed information is needed on the chemical composition and nutritional quality of potential estuarine food items, as well as the ability of species of concern to feed on these items. The issue is made more complex because: 1) organisms vary in their ability to derive nutrition from given foods and 2) the availability of food items varies within and among estuaries as well as over time. Relatively little is known about the factors that determine the acceptability of foods to a species or a particular life-history stage. In addition, better understanding is needed of the ecological "trade-offs" that may be involved with feeding on larger quantities of low-quality food. In this regard, research on the following questions should be pursued: 1) What factors determine the importance of plankton-based versus detritus-based food webs in individual estuaries? 2) How are plant and animal matter processed in estuarine food webs? and 3) What are the relative magnitudes of organic matter import to, export from, or sedimentation in estuaries?

1d. Determine the relative magnitude of organic matter input to, export from, and sedimentation in representative ecosystems.

The pool of organic matter available to estuarine food webs depends on the primary production within systems, the import of organic matter from oceanic, terrestrial, and fluvial sources, the export of organic matter to coastal waters, and the balance between materials sequestered in benthic sediments versus those that are resuspended by physical events or bound in biological activity. This type of information is not available or complete, except perhaps in the most heavily studied estuaries, yet it is essential for assessing and comparing the coupling of primary and secondary production among systems or within a system over time. Resources should be devoted to developing such estimates for a representative suite of estuaries around the country.

2. How are trophic pathways affected by natural events and human activities?

Considerable evidence exists to demonstrate that the addition of large quantities of wastes (toxic as well as non-toxic) from human activities can bring about detrimental changes in estuarine ecosystems. Evidence also suggests that stocking practices, particularly in the Great Lakes, and fishing can alter the complexion of predatory species and, in turn, result in fundamental changes in estuarine food web dynamics. By-and-large, such observations stem from studies of grossly polluted systems or systems whose fauna have been significantly altered as a result of fisheries management practices. Even in the most intensely studied estuaries, ecosystem response generally is understood on a qualitative rather than a quantitative level. Models may exist that permit retrospective analyses, but rarely is prediction of ecosystem response possible. In order for a link to be made between improved understanding of estuarine trophic dynamics and the influence of human perturbations of estuarine ecosystems, the following must be addressed:

2a. Understand how the addition of biostimulatory materials may alter trophic dynamics by affecting rates and pathways.

Considerable evidence suggests that the addition of biostimulants, especially organic carbon, phosphorus (in freshwater), and nitrogen (in marine systems) can lead to detrimental changes in aquatic food webs. Low levels of nutrients may actually enhance primary production and increase the biomass of desirable organisms. However, sustained, high-volume additions of organic matter or nutrients generally produce undesirable shifts in community structure (i.e., species, size, and composition) and environmental quality. As a result of associated changes in trophic dynamics, the accumulation of pollutants in sediments, and the recycling of excess carbon and nutrients, effects may continue after the sources of pollution are removed. Research efforts in this area should focus on acquiring a better understanding of the factors that determine the trophic rates and pathways. Under such conditions, the roles and dynamics of the microbial components are of special interest. Also of concern to both environmental managers and scientists are the incremental and cumulative effects of biostimulants, and the reversibility of such effects.

2b. Determine how the addition of toxic materials alter trophic dynamics.

In contrast to our understanding of the process of eutrophication, relatively little is known about the trophic implications of toxicant additions. Research has focused largely on correlative field observations or on laboratory experimental studies of effects on organisms, their tissue, and cellular levels. Relatively little work has focused on population- or community-level effects. However, the laboratory studies conducted have demonstrated that many pollutants have the potential to influence processes governing plankton growth (e.g., respiration and photosynthesis) and to produce acute or sublethal effects in individual planktonic organisms. Other experimental evidence suggests that exposure to chlorinated hydrocarbons or toxic metals such as copper and mercury may cause shifts in the dominant cell size of phytoplankton populations from larger to smaller forms.

Many questions that were raised on the trophic effects of biostimulatory materials are also pertinent to the effects of toxic substances. However, the issue is complicated by the many combinations of contaminants that may occur within individual estuaries. A piecemeal toxicant-by-toxicant approach may prove less efficient than investigations on the suite of contaminants present at individual study locales, followed by attempts to make generalizations and identify similarities with results from other sites. To address this task, research should: 1) determine the mechanisms and extent to which toxicants cause alterations of estuarine food webs; 2) determine the point at which, for selected contaminants, the addition of a specific toxicant causes significant alteration in estuarine food webs; and 3) determine to what degree toxicant-mediated trophic changes are reversible.

3. What are the relative effects of fishing, pollution, and natural mortality on fishery population dynamics?

The primary question with regard to pollution and natural events that cause mortality is: What is their relative contribution to fish mortality in relation to that caused by fishing pressures? This must be considered against a backdrop of natural mortality (e.g. due to currents which sweep larvae to areas lacking sufficient food) and mortality caused by human activities (habitat alteration). Priority tasks are:

3a. Develop basic life-history and population data for estuarine-dependent species.

Fishery biologists have developed and used models to relate population and recruitment information to predict future stock abundance, particularly for offshore stocks. We need to develop basic fishery information on the early life stages of estuarine-dependent species so that similar approaches can be developed and used for these species as well. This task will require a substantial increase in efforts now being conducted independently and to varying degrees in each coastal state. Specifically, these efforts need to be augmented and coordinated.

3b. Use models to quantify the effects of fishing mortality on populations of representative species in relation to estimates of population loss resulting from human activities and natural factors.

For selected species, we need to determine the relative contributions of fishing pressures, environmental effects, pollution, and habitat alteration that lead to mortality. For species that have significant mortality attributable to human-induced causes, additional information on population dynamics, reproduction and recruitment will be needed to clarify the primary causes of such mortality. This approach, if successful, should be utilized for those species regionally whose population dynamics are related potentially to stress by human activities, particularly estuarine-dependent species that are or will be subject to habitat-related mortality caused by chronic factors.

4. What are the ecosystem impacts of harvesting and stocking fishery resources on food web dynamics and predator-prey interaccions?

Recent studies in the Great Lakes have demonstrated the significance of stocking and selective harvesting in shaping aquatic food webs. These practices have the ability to change the composition of predator populations and, in so doing, alter the mix of primary producers. The changes are similar to those associated with the addition of excess nutrients and organic carbons. These studies have resulted in a spirited environmental debate on the relative importance of predation versus eutrophication in determining the nature of coastal and estuarine food webs.

Despite the success of such studies in the Great Lakes, little similar work has been attempted in estuarine environments. Greater effort should be devoted to examining the impact of selective harvesting on estuarine trophic interactions. Estuarine fish and shellfish populations are often heavily exploited, and the possible breakdown of mechanisms that normally keep populations in check has been suggested as a contributing factor to the occurrence of nuisance algal blooms in the Northeastern and middle Atlantic estuaries. Priority areas related to this problem are: 1) determine whether, for representative ecosystems, harvest-related population declines are a major factor in causing change in trophic structure and, if so, what the mechanisms are; 2) determine how extensive and long-lasting the changes are; and 3) determine at what point fishery practices cause significant alterations in food web functioning and whether they are reversible.

C. Synthesis and Prediction

1. What conceptual approaches (models) can be developed and used to relate fishing mortality to that caused by habitat degradation and natural factors?

A priority need in determining the effects of human activities on estuarine-dependent living marine resources is the ability to relate mortality caused by fishing pressure to that caused by natural factors, pollution, and habitat loss. This can be simulated by development of conceptual approaches that may lead to numerical models. Developing such conceptual approaches will require considerable expert thought. Developing the information on population dynamics, reproductive success, growth rates, etc., will require substantial basic fisheries research (as specified above). Priority tasks are: 1) from population data developed above, evaluate and synthesize the relevant data on population size, recruitment, harvest, etc., for use in evaluating natural variability in relation to human-caused stress and harvest mortality; 2) evaluate the effects of stress on selected species population characteristics; 3) from available methologies, develop the conceptual approach that will best allow a prediction of population response to harvest, natural, and human-caused factors; 4) test the approach by simulating population responses to various combinations of mortality attributable to fishing pressure, natural factors, and "pollution"; and 5) convene a national workshop to review and improve the model.

2. What are the cumulative effects of human activities (including physical alteration, introduction of contaminants, nutrient over-enrichment, changed freshwater inflows, altered circulation patterns, and fishing pressure) on important fishery populations?

It is necessary to combine the models of population changes attributable to all major habitat changes in relation to fishing mortality and natural mortality. The ability to develop such a conceptual basis for prediction is at this point speculative but is considered to be a prime objective. Priority tasks related to this problem are: 1) evaluate all models needed to assess cumulative effects for several representative regions having human-caused problems that potentially affect estuarine-dependent populations of concern; 2) assemble and organize data for all components of the selected model and for all major threats for specific ecosystems; 3) evaluate data quality and take steps to assure data adequacy; 4) conduct modeling of all factors affecting a population and evaluate results; 5) convene national workshop to review and improve cumulative effect assessment; and 6) assess additional species and ecosystems.

3. What are the trade-offs (i.e., economic, ecological, and social) for various national or regional estuarine and coastal policy options?

An assessment is needed to guide national policy decision-making for estuarine and coastal habitat and resource management. Such an assessment should consider the biological, economic, and social factors that will be effected by various policy options. However, for such an assessment to be useful, estuarine and coastal ecosystem values to society must be adequately determined using methods that incorporate the true benefits of such resources. Outdated, simplistic approaches have not resolved these conflicts because the true value of such ecosystems to society are difficult to quantify. Innovative approaches must be developed for trade-off analysis to become an acceptable means of policy development. Priority tasks related to this question are: 1) assemble and evaluate data needed to make cumulative assessment of ecosystem effects of policy options for a test ecosystem; 2) obtain adequate economic methodology to assess economic effects of resource changes, changes to the general quality of life and costs of alternative land-use decisions; 3) develop methodology to relate effects of policy options in terms of ecosystem productivity, quality of life and traditional economics; 4) evaluate policy options using relational methodology; 5) predict effects and consequences of various policy options; and 6) convene a national workshop to review assessment.

4. What are the predicted consequences of proposed or existing fishery management regulations?

We need to be able to predict the consequences of proposed fishery management actions on future stock dynamics. Currently, our ability to predict future stock abundance is limited by a lack of basic fishery information on early life-history stages, particularly for estuarine-dependent species. Moreover, our scientific data on the population characteristics of even the best known species are less than sufficient for our needs, primarily because of the breadth of the area involved and the difficulty of dealing with living resources and their myriad variations of abundance, growth, survival, etc. Predicting the effects of fishery regulations on such an imperfect base of knowledge is a substantial challenge. Priority tasks related to this problem are: 1) select a species appropriate for study and evaluate necessary data on population structure, fishing pressure, pollution and habitat alteration threats, etc.; and 2) compare the effects of alternative management options using cumulative assessment methodologies described above.

5. What are the priority estuaries for NOAA's scientific attention?

An assessment is needed to establish priorities for additional, site-specific estuarine and coastal ecosystems effort. This assessment should consider the importance of the ecosystem in providing long-term, sustained biological productivity of those species of interest to man and that may be experiencing or expected to experience stress that could limit productivity. Our purpose would be to identify those systems in need of immediate NOAA attention to resolve specific environmental problems. These can be identified using an approach such as the following: 1) assemble a synthesis of comparable data from all major U.S. estuaries on living resource value and importance, contaminant and nutrient loads, flushing rates, sediment characteristics, and land-use status and projections; 2) develop relational methodology to compare estuaries' features and characteristics; 3) apply methodology using available data; and 4) evaluate results and refine as necessary.

Chapter VI

FRAMEWORK IMPLEMENTATION

CHAPTER VI

FRAMEWORK IMPLEMENTATION

I. IMPLEMENTATION STRATEGY

NOAA's organization for implementing the Estuarine and Coastal Ocean Science Framework is shown in Figure 15. The Chief Scientist, in consultation with the Assistant Administrators of the NOAA line offices, will oversee implementation of the Framework and related Program Plans. The Estuarine Programs Office (EPO), within the Office of the Chief Scientist, will coordinate activities and provide administrative support, while the Estuarine and Coastal Ocean Policy Committee will provide technical and policy guidance for the Chief Scientist.

To carry out the science strategy of the Framework, NOAA will focus its multi-disciplinary resources and capabilities on the problem areas described therein. Primarily, this will be accomplished through the development of Estuarine and Coastal Ocean Science Program Plans, which will detail NOAA's estuarine program direction on a yearly basis, using the Framework as overall guidance. Through the annual review of Program Plans, priorities will be set for estuarine activities in the upcoming year. These Program Plans will include a description of progress made by NOAA in addressing the long-range strategy of the Framework.

In conducting Program Plan activities, NOAA will rely on its vast network of research facilities and programs, which encompass the full geographic and scientific scope necessary for accomplishment of Framework goals. The EPO will work closely with the line offices to ensure that the Agency's management and technical capabilities are closely integrated, and that all activities conducted or funded by NOAA in connection with Framework implementation adhere to the protocols of the NOAA quality assurance program.

Office of the Chief Scientist

NOAA's Chief Scientist will be responsible for establishing policy, guiding program activities, and resolving conflicts over program priorities within NOAA. Decisions regarding the initiation, enhancement or redirection of specific estuarine program activities will be made by the Chief Scientist in consultation with the Assistant Administrators and the Under Secretary, through the annual review of Estuarine and Coastal Ocean Science Program Plans.

Organization for Implementation of the
NOAA ESTUARINE &
COASTAL OCEAN FRAMEWORK

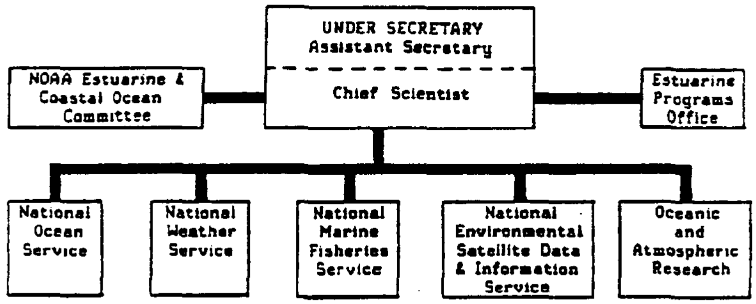


FIGURE 15

Under the direction of the Chief Scientist, EPO will develop annual Program Plans in consultation with the NOAA line offices. These Program Plans will include a report on NOAA's progress in meeting the objectives of the Framework. The report will also suggest options for improving coordination and efficiency among NOAA's estuarine and coastal programs, including activities in estuarine research and assessment, fisheries research, coastal management, and habitat conservation. In addition, the Program Plans will describe NOAA's estuarine and coastal activities in relation to the endeavors of other Federal and state agencies. The report will examine how NOAA's activities and products (data, technical findings, analyses, interpretive documents) relate to those of other agencies and identify cooperative activities to be initiated, enhanced, or redirected in the future.

To advise the Chief Scientist on the implementation of the Framework, an Estuarine and Coastal Ocean Policy Committee will be established. The committee will be comprised of representatives from each NOAA line office. Personnel from the Sea Grant universities, state coastal management programs and state fisheries agencies will be invited to advise the committee on selected issues. The committee will meet regularly to review progress on the Framework, and will provide recommendations to the Chief Scientist on improving NOAA's estuarine and coastal programs.

Facilities and Programs

NOAA's principal laboratories, support facilities, and data centers are shown in Figure 16. The NOAA fleet, as described in Figure 17, contributes technical and logistical support to the research programs of these facilities. In addition, NOAA also administers the Sea Grant College Program and the Estuarine Research Reserve System, as well as the coastal zone and fisheries management programs that link NOAA to the coastal states. These facilities and programs are shown in Figure 18.

The Sea Grant system is a network of twenty-nine programs located on the Atlantic, Gulf of Mexico, Pacific, and Great Lakes coasts conducting marine research, education, and advisory services. Administered by NOAA's Office of Oceanic and Atmospheric Research, the Sea Grant system provides NOAA with direct links to the Nation's university community. It also provides a unique mechanism for forging a scientific partnership between the Federal Government and the states.

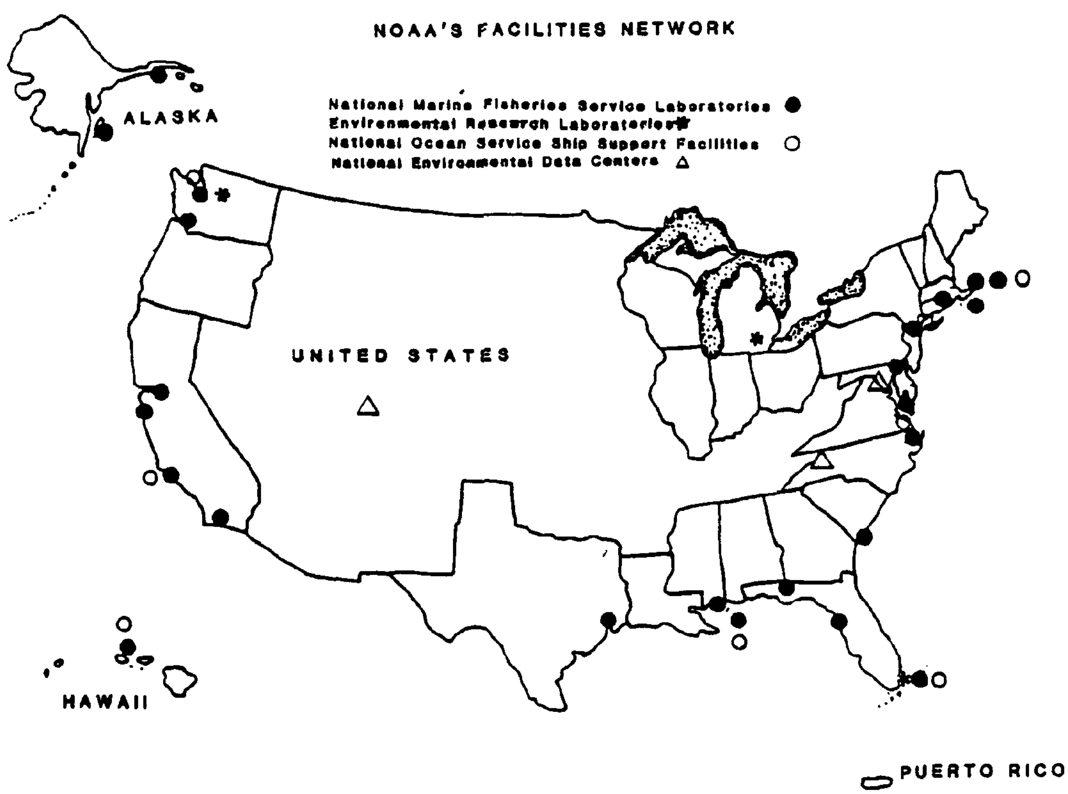


FIGURE 16

The NOAA Fleet

CLASS	NOAA SHIP	HOME PORT	Length (feet)	Displacement (tons)	Cruising Speed (knots)	Endurance (days)	Survey Launches	Scientific Accommodation	Bow Thruster	Helicopter Platform	Laboratory	Charting & Mapping	Environmental Assessment	Fisheries Research	Oceanographic & Atmospheric Research
			GENERAL DESCRIPTION									MISSION			
I	Oceanographer	Seattle, WA	303	4,000	11	31		24	●		●				●
	Discoverer	Seattle, WA	303	4,000	11	31		24	●		●	●			●
	Researcher	Miami, FL	278	2,993	13	31		16	●	●	●				●
	Surveyor	Seattle, WA	292	3,440	12*	28		16	●	●	●	●			●
II	Fairweather	Seattle, WA	231	1,800	11	22	4	4	●		●	●			
	Rainier	Seattle, WA	231	1,800	11	22	4	4	●		●	●			
	Mt. Mitchell	Norfolk, VA	231	1,800	11	22	4	4	●		●	●			
	Miller Freeman	Seattle, WA	215	1,920	12	31		11	●		●		●	●	
III	Peirce	Norfolk, VA	163	907	12	30	2	2				●			
	Whiting	Norfolk, VA	163	907	12	30	2	2				●			
	McArthur	Seattle, WA	175	995	10	28		6			●		●	●	●
	Davidson	Seattle, WA	175	995	10	23	2	2			●	●			
	Oregon II	Pascagoula, MS	170	952	12	31		15			●			●	
	Albatross IV	Woods Hole, MA	187	1,089	10	16		15	●		●			●	
IV	Townsend Cromwell	Honolulu, HI	163	652	10	30		9			●			●	
	David Starr Jordan	San Diego, CA	171	993	10	31		13	●		●			●	
	Delaware II	Woods Hole, MA	156	750	11	24		9			●			●	
	Chapman	Pascagoula, MS	127	520	9	14		6	●		●			●	
	Ferrel	Norfolk, VA	133	380	8	8		6	●		●		●		
V	John N. Cobb	Seattle, WA	93	250	9	13		4			●			●	
	Rude	Norfolk, VA	90	220	8	3		0				●			
	Heck	Norfolk, VA	90	220	9	3		0				●			
VI	Murre II	Juneau, AK	86	295	9	8		5			●			●	

FIGURE 17

NOAA'S COASTAL ZONE MANAGEMENT PROGRAMS,

NATIONAL ESTUARINE RESEARCH RESERVE SYSTEM

&

NOAA'S SEA GRANT UNIVERSITY NETWORK

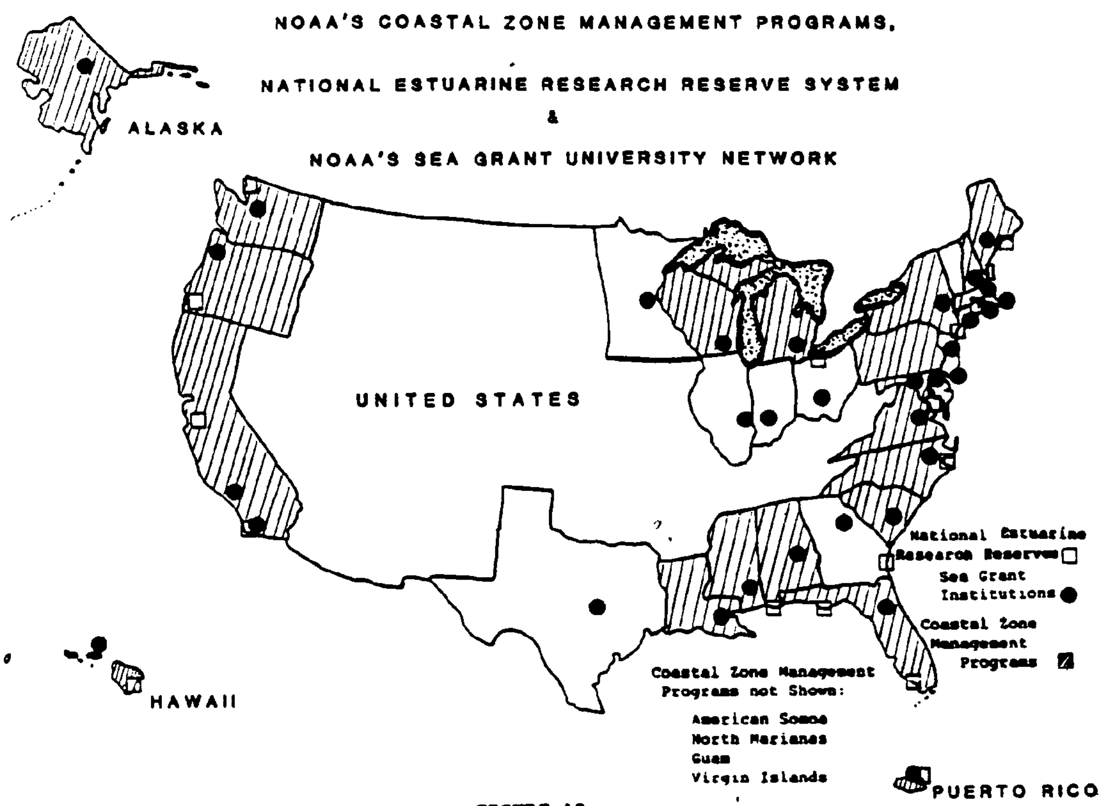


FIGURE 18

The National Estuarine Research Reserve System is administered by NOAA's National Ocean Service. It consists of carefully selected estuarine areas of the United States that are designated, preserved, and managed for research as well as educational purposes. The reserves are chosen to reflect regional differences and to include a variety of types in accordance with the classification scheme of the national program. Because all of the reserves are part of a national system, they collectively provide a unique opportunity to address the estuarine research and management issues of the Framework.

Federally-approved state coastal zone management programs exist in twenty-nine states and territories. Operating under the auspices of NOAA's National Ocean Service, these programs work through a state-agency coordination/oversight role, for day-to-day management of estuarine and coastal ocean resources. The state-level coastal management agencies will clearly benefit from NOAA's scientific efforts, and also will provide insight into how NOAA's future science agenda will be shaped.

Under authority of the Fish and Wildlife Coordination Act, the National Marine Fisheries Service's Habitat Conservation Program addresses all forms of estuarine and coastal development affecting living marine resources and their habitats. It is staffed by biologists and other technical specialists in NOAA facilities in most coastal states. The mission is to evaluate proposed projects, programs and policies of other Federal agencies (or authorized by such agencies) and to make scientific recommendations in the public interest to conserve habitats important to living marine resources. This program is a primary user of the information to be developed under the Framework as it is directly involved in influencing decision-making affecting estuarine and coastal ecosystems.

II. INTERNAL COORDINATION

The coordination of research efforts and communication of scientific information to resource managers and other users is an important aspect of NOAA's responsibilities. Daily, NOAA is required to draw upon its scientific expertise in forming comments, recommendations, and position statements on proposed water development or other land-use projects that may adversely affect marine resources for which NOAA has management responsibility. It is critical that NOAA use the best scientific information available for these purposes. However, research conducted at specific locales is often narrowly focused in terms of discipline or subject area. A thorough synthesis of the information available throughout NOAA's facilities, as well as from other agencies and institutions, is imperative. NOAA needs an ongoing capability to synthesize and translate research findings into forms that will be useful to resource decision-makers on a local, regional, state, and Federal level. In order to fill this need the following efforts will be initiated:

- <u>To assure a strong coastal/estuarine focus that links coastal communities, academic scientists, resource managers, and other users, cooperative arrangements among NOAA-sponsored programs will be encouraged</u>. These cooperative programs could: 1) conduct applied research to answer questions directly related to regional resource management needs; 2) analyze and synthesize existing information concerning problems that affect regional estuarine/coastal environments; and 3) develop educational programs for local, county, state, and Federal agency representatives whose decisions are crucial to the health and maintenance of regional estuarine and coastal habitats.

- <u>To better communicate estuarine and coastal ocean data and information, an electronic data exchange will be established to link NOAA, Sea Grant institutions, Estuarine Research Reserves, and coastal management programs</u>. Eventually, such an exchange might be extended to include other Federal and academic facilities, as well. To minimize costs, this network should be based on existing systems (e.g. through NESDIS/NODC systems, SIGNET, OMNET, etc.). The specific software parameters and hardware characteristics appropriate for this system must also be explored in the context of existing NOAA capabilities. Such a system would significantly enhance NOAA's ability to communicate rapidly and in a comprehensive manner to all of its estuarine and coastal ocean related facilities and programs, and assure more effective coordination with the program activities of other Federal agencies.

- <u>To provide a cohesive national program, a scientific network will be initiated</u>. A directory of the facilities participating in this network would describe areas of expertise. In addition, workshops could be held at the participating facilities to address particular issues of national concern. This network of facilities would also serve as a mechanism to organize and survey national estuarine and coastal ocean priorities. The results of such a survey would support an estuarine/coastal data base constructed to identify the most critical issues and problems for NOAA and the Nation to address.

III. APPLICATION TO MANAGEMENT PROGRAMS

The application of Framework results to NOAA's management programs is an important aspect of the Agency's work. Estuarine and coastal research must be planned and conducted in a management decision-making context. This will encourage the application of scientific findings to decisions for reducing water quality degradation, minimizing habitat destruction and conserving the living resources of the Nation's estuaries. The programs and facilities described above provide a crucial mechanism for directing and applying NOAA research and information products to the management needs of Federal, regional, state, and local decision-makers.

NOAA's management programs provide a valuable mechanism for implementing scientific findings. Through its coastal zone and fisheries habitat conservation and management responsibilities NOAA has oversight responsibility and grant authority to provide support to coastal states for vital resource programs. To link the scientific and technical information developed through the Framework with progress made by the coastal states, NOAA will rely on the existing network established through coastal, fisheries, and habitat conservation and management authorities.

- <u>To encourage effective management of coastal resources at the state level, NOAA will rely on the grant and review authority of the Coastal Zone Management Act</u>. Through this Act, NOAA and participating coastal states are able to evaluate key resource issues such as those identified in the Framework: freshwater inflow alterations, contaminants, habitat degradation, and declines in living resources. Evaluation of state efforts to address these issues will assist NOAA in making recommendations for improvement. Improvement activities will be monitored as annual work program tasks or as "significant improvements in the national interest" under Section 303(2) of the Coastal Zone Management Act. Information on coastal state progress in addressing estuarine and coastal management issues will be collected by NOAA, synthesized, and transferred back to the states to describe the status of the problem from a national perspective and identify states that may have innovative or particularly creative approaches for dealing with particular resource management problems. Such a collection effort would be accomplished at a relatively low cost, as it would rely on existing in-house capabilities.

- <u>To encourage effective management of inter-jurisdictional fisheries, NOAA will rely on the grant authority provided in P.L. No. 99-659 to promote and encourage state data-gathering activities and fishery management</u>. Title III of this new law, which replaces the Commercial Fisheries Research and Development Act of 1986, increases the ability of NOAA to select projects and apply conditions that will focus funding on higher priority inter-jurisdictional fisheries needs. The Anadromous Fish Conservation Act provides for grants to states and other entities concerned with anadromous fish. NOAA will focus attention on using this grant authority to address the needs identified in the Framework.

- <u>To encourage habitat protection, NOAA's Habitat Conservation Program will step up its research and management efforts to address short- and long-term effects and begin an initiative with the Regional Fishery Management Councils to adopt a habitat policy with an objective of no net habitat loss</u>. Under the Magnuson Fishery Conservation and Management Act, as amended in 1986, the Councils must now address habitat issues in each fishery management plan, and may require Federal agencies to respond to their inquiries regarding habitat concerns and issues. NOAA's Habitat Conservation Program will increase regional assistance to the Councils to support this effort.

IV. FEDERAL COORDINATION

Responsibilities for science, management, and regulation of estuarine and coastal ocean resources are distributed widely among executive agencies. In addition to NOAA, Federal agencies such as the Fish and Wildlife Service, the Corps of Engineers, the Environmental Protection Agency, the U.S. Geological Survey, the National Aeronautics and Space Administration, the U.S. Coast Guard, and Department of Agriculture, all have programs and reponsibilities that significantly affect the use and understanding of estuarine and coastal resources. It is critical that Federal agency actions be conducted in a coordinated manner, to minimize duplication of effort and ensure that a common understanding of each agency's core role in addressing estuarine/coastal issues is recognized. Coordination of Federal efforts in this area is also critical for assuring the availability of the best scientific information for resource management purposes.

- <u>To assure effective Federal agency coordination an ad hoc inter-agency committee will be formed, representing the agencies that conduct estuarine and coastal ocean programs</u>. This <u>ad</u> <u>hoc</u> committee would meet on an as-needed basis to identify strategies appropriate for coordinating major national coastal/estuarine program initiatives, and to define more clearly the respective Federal roles and responsibilities in the multi-jurisdictional estuarine and coastal environments. The committee will take maximum advantage of existing interagency groups that have responsibilities paralleling those of the <u>ad</u> <u>hoc</u> committee, such as NOAA's National Ocean Pollution Policy Board. Furthermore, if the Policy Committee determines that a formalized mechanism is appropriate for a particular pollution-related issue, the National Ocean Pollution Policy Board could be used for that purpose.

V. FUTURE OUTLOOK

Estuarine and coastal science is at an important threshold. Computer and satellite technologies enable us to consider questions that were once unimaginable. We can stand outside the biosphere and observe this system, monitor changes on global scales and collect, store, and analyze billions of bits of data almost instantaneously. Science and technology present an enormous opportunity and equally large challenge -- the challenge to understand through rigorous and creative inter-disciplinary science the consequences of the often unwitting and pervasive manipulation of the estuarine and coastal ecosystem. Slowing the momentum of these degenerative processes cannot be accomplished overnight. The impact of decades of toxic pollution, of habitat destruction, and resource extraction will shape the estuarine and coastal environment for many future generations. However, the opportunity to harness these negative forces lies in effective application of new technical skills and commitment -- long-term, sustained commitment -- to directing attention and resources to the needs of this most productive of marine environments.

The Estuarine and Coastal Ocean Science Framework is NOAA's first step in that renewed commitment. Through this Framework, the Agency will dedicate its talents and resources to the Nation's nearshore waters. This is a dedication that will carry beyond the current wave of enthusiasm well into the next century. We believe that the science focus we have adopted, the collaborative efforts we anticipate with other agencies, and support for this endeavor from the citizenry will make a dramatic difference for the future of our estuarine and coastal ocean systems.

NOAA Estuarine and Coastal Ocean Science Framework

October 1987

Appendices

NOAA Estuarine and Coastal Ocean Science Framework

APPENDICES

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APPENDIX A

Legislative Crosscut

NOAA's Estuarine Legislative Crosscut

National Oceanic and Atmospheric Administration
Anthony J. Calio, Administrator

NOAA Estuarine Programs Office
Virginia K. Tippie, Director

NOAA's authorities to assess or describe estuaries, to conduct research in the estuaries and to help manage estuarine resources is founded on a plethora of Federal legislation spanning decades. In fact, as early as the late nineteenth century, the National Marine Fisheries Service and the Coast and Geodetic Survey (organizations which later became a part of NOAA) were governed by legislative mandates that affected the estuaries. Since then, Congress has enacted legislation that confers greater authority on NOAA to address specific issues such as fishery management, pollution research, and the determination of tides and circulation - all of which require efforts within the estuaries.

Despite NOAA's many estuarine legislative authorities, no document has been developed that specifically relates this legislation to NOAA's estuarine programs. The estuarine legislative crosscut addresses this by integrating NOAA's estuarine responsibilities with Congressional intent. The crosscut identifies the primary pieces of legislation that give NOAA authority to coordinate estuarine programs and to undertake efforts in assess- ment, research, and management. It is not intended to be a comprehensive analysis of estuarine-related legislation, nor a compendium of laws. Instead, the crosscut links activities with specific sections of Federal legislation and creates a framework within which to understand NOAA's responsibilities for the estuaries.

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INTER AND INTRA-AGENCY PLANNING

NOAA was granted broad estuarine coordinating and planning authority in the Fall of 1986, when Congress established the Estuarine Programs Office within NOAA to develop a national estuarine strategy for the Administration that integrates its research, regulatory and trusteeship responsibilities. The law charged this office to coordinate not only NOAA's internal programs in estuarine research and assessment, fisheries research, coastal management, and habitat conservation, but also its external efforts with other Federal and state agencies.

With the passage of the Water Quality of 1987, EPA and NOAA are now required to submit, jointly, a biennial report describing the health of the Nation's estuaries. In addition, EPA is to provide up to $5,000,000 annually to NOAA for ecosystem and trend assessment, a water quality sampling program, and estuarine research.

Amendments to the National Ocean Pollution Planning Act established the National Ocean Pollution Programs Office within NOAA to prepare a 5-year plan to order national ocean pollution needs and problems. Many of the pollution issues occur with the Nation's estuaries. The Office also is responsible for reviewing budget requests from all Federal Agencies.

CAPABILITIES	LEGISLATION	DESCRIPTION
INTER AND INTRA-AGENCY PLANNING		
NOAA Intra-Agency Planning		
• Estuaries: NOAA Estuarine and Coastal/Ocean Science Framework	Magnuson Fishery Conservation and Management Act Amendments of 1986, Pub. L. No. 99-659, Sec. 406	Administrator of NOAA shall establish an Estuarine Programs Office to develop and implement a national estuarine strategy that integrates the research, regulatory,and trusteeship responsibilities of the Administration, and to coordinate the estuarine activities of the various organizations within the Administration including activities in estuarine research and assessment, fisheries research, coastal management, and habitat conservation.
NOAA Inter-Agency Planning		
• National Estuary Program	Magnuson Fishery Conservation and Management Act Amendments of 1986, Pub. L. No. 99-659, Sec. _______	The NOAA Estuarine Programs will coordinate the estuarine activities of the Administration with the activities of other Federal and state agencies and provide technical assistance to other Federal agencies, and to state and local agencies.

CAPABILITIES	LEGISLATIVE	DESCRIPTION
INTER AND INTRA-AGENCY PLANNING		
• National Estuary Program	Water Quality Act of 1987, Pub. L. No. 100-4, Sec. 320	The EPA Administrator shall provide up to $5,000,000 per fiscal year of sums to be appropriated to NOAA to carry out research in estuaries for long-term trend assessment, ecosystem assessment, comprehensive water quality sampling, and identification of the movements of nutrients, sediments, and pollutants through estuarine zones and their impacts.
• Five Year Pollution Plan	National Ocean Pollution Planning Act of 1978, 33 U.S.C. 1702, as amended	The Administrator of NOAA shall establish the National Ocean Pollution Program Office to review each department agency pollution budget request and, in consultation with other appropriate Federal officials, prepare a comprehensive 5-year plan for the overall Federal effort in ocean pollution research, and development and monitoring.

I. ESTUARINE ASSESSMENT

Estuarine assessment is the first step in describing an estuarine system. Assessment addresses the physical environment, water and sediment quality, and associated animals and plants. To assess an estuary, existing information must first be identified and analyzed. This step reveals where additional data are necessary to complete the assessment. NOAA programs, therefore, include archiving and analyzing data and developing descriptions of the estuarine environment.

DATA ARCHIVES. NOAA maintains extensive archives for oceanographic, climatic, satellite, fisheries, and pollution data, much of which are available to the public upon request. NOAA also publishes an annual catalogue of all of its estuarine-related activities and disseminates annually an inventory of all Federal pollution research.

DATA ANALYSES. Data analyses entail gathering information from a variety of sources and standardizing it. NOAA's data analysis activities include building data bases on physical, chemical, and biological factors, as well as on land-use patterns. Much of this information is currently being incorporated into a comprehensive data base, the National Estuarine Inventory (NEI). The NEI covers 92 U.S. estuaries. Much of this information is graphically displayed in a series of data atlases. Analyzing data bases also is part of NOAA's assessment programs. In major estuaries such as the Chesapeake Bay and Puget Sound, NOAA analyzes data to assess the effects of weather and oceanographic conditions on fisheries, recreation, and transportation.

ENVIRONMENTAL DESCRIPTION. A number of NOAA's programs describe the status of estuarine systems, resources, or levels of contaminants. These programs rely on observational data collection and monitoring. The data generated are used to predict trends in environmental quality and abundance of living resources. NOAA's nautical charting and tides and circulation programs fall under the category of environmental description and provide valuable information to the maritime industry and recreational boaters.

CAPABILITIES	LEGISLATIVE	DESCRIPTION
ASSESSMENT		Describe the estuarine system: Physical environment, water and sediment quality, plants and animals.
ARCHIVES		
• Oceanographic and Geodetic Data	National Ocean Survey 33 U.S.C. 883(a-e)	Conduct hydrographic and topographic surveys; take tide and current observations; compile, analyze, process and publish data and charts.
• Weather, Climate & Satellite Data	National Climate Program Act 15 U.S.C. 2904	Conduct global data collection; assess the effect of climate on the natural environment; develop systems to manage and disseminate climatological data.
	Weather Service Organic Act 15 U.S.C. 313	Collect and distribute meteorological information and record climatic conditions of the United States.
	Land Remote-Sensing Commercialization Act of 1984, 15 U.S.C. 4203	Policy of the United States to acquire and disseminate remote-sensing data.

CAPABILITIES	LEGISLATION	DESCRIPTION
ASSESSMENT		
	Federal Aviation Act 49 U.S.C. 1463	Promote and develop meteorological science and support research projects in meteorology.
DATA ANALYSIS		
• National Estuarine Inventory	Marine Protection, Research and Sanctuaries Act Title II, 33 U.S.C. 1441 et seq.	Develop comprehensive research program: long-range effect of pollution, overfishing and man-induced changes of ocean ecosystems; cooperate with EPA in assessing feasibility of regional management plans for coastal disposal of waste.
	Agriculture Marketing Act 7 U.S.C. 1622(g)	Improve standards and quality of fish and shellfish products.
• Environmental Assessments	National Climate Program Act 15 U.S.C. 2904	Develop systems to manage and disseminate climatological information and assessments.

CAPABILITIES	LEGISLATION	DESCRIPTION
ASSESSMENT		
	National Environmental Policy Act 42 U.S.C. 4332	Prepare an environmental impact statement for major Federal actions that significantly affect the quality of the human environment.
	Federal Water Pollution Control Act, as amended (Clean Water Act) 33 U.S.C. 1321	Assess injury, destruction, or loss of natural resources in the coastal and marine environment caused by discharge of oil from vessels or onshore or offshore facilities.
	Comprehensive Environmental Response, Compensation and Liability Act, (Superfund) 42 U.S.C. 9607, 9611	Assess injury, destruction, or loss of natural resources in the coastal and marine environment caused by releases of hazardous substances from facilities.

CAPABILITIES	LEGISLATION	DESCRIPTION
ASSESSMENT		
ENVIRONMENTAL DESCRIPTION		
• Navigation, charting tides, circulation	National Ocean Survey 33 U.S.C. 883a-e, 44 U.S.C. 1310	Provide charts for safe navigation; conduct tide and current observations; publish tide tables, and maps; print and distribute nautical charts; cooperate with other agencies and private organizations.
• Stock Assessment	Magnuson Fishery Conservation and Management Act 16 U.S.C. 1853(a)(3)	Assess present and future conditions of fishery stocks.
	Anadromous Fish Conservation Act 16 U.S.C. 757b	Conduct biological surveys to conserve, develop, and enhance anadromous fish.
• Monitoring		
	Marine Protection, Research and Sanctuaries Act Title II 33 U.S.C. 1441 et seq.	Develop comprehensive research program on long range effects of pollution; assess the capacity of the marine environment to receive materials without degradation; monitor programs and assess the health of the marine environment, including contaminant levels in biota, sediments, fish and shellfish.

CAPABILITIES	LEGISLATION	DESCRIPTION
ASSESSMENT		
	National Ocean Pollution Planning Act 33 U.S.C. 1701 <u>et</u> <u>seq</u>.	Monitor research efforts of other Federal agencies and use of such research in determinations that affect the environmental quality of the Great Lakes, Chesapeake Bay, Puget Sound and other estuaries of national significance.

II. ESTUARINE RESEARCH

The review and synthesis of data gathered in the characterization phase helps to identify topics where additional research is needed to support management decisions. NOAA's estuarine research activities emphasize physical processes, ecosystem dynamics, and living marine resources and their habitats. Research on the effects of contaminants on estuarine organisms and their subsequent effect on fisheries utilization is also conducted.

PHYSICAL PROCESSES. Circulation patterns, together with chemical and biological processes, are important in determining the fate of contaminants introduced into an estuary. NOAA, therefore, has research programs on circulation dynamics and contaminant transport which emphasize how estuaries trap dissolved, as well as particle-born, pollutants. NOAA also is examining the role that benthic organisms play in both resuspending and transporting contaminants.

ECOSYSTEM AND NUTRIENT DYNAMICS. Estuaries are among the most productive ecosystems in the world. This productivity is due partly to nutrients and their role in stimulating biological growth, although much is still unknown. Circulation patterns, nutrient dynamics, primary production, and decomposition combine to create a constantly varying environment. To better understand these relationships, NOAA researchers are investigating the dynamics of food webs in estuaries and the role of nutrients and physical conditions in regulating productivity.

LIVING RESOURCES. NOAA has extensive research programs designed to study finfish and shellfish. To understand natural and anthropogenic factors affecting their productivity, NOAA investigates the life history of economically important fish and shellfish to determine their biological requirements. NOAA also investigates diseases in a number of species and conducts aquaculture research to artificially create environments that can support valuable living resources such as salmon, striped bass, and shrimp.

ESTUARINE HABITATS. Estuarine habitats, vital to commercial and recreational fisheries, are threatened by development-related activities such as disposal of sewage and industrial wastes, dredging, filling, freshwater diversions, damming, and channelization. Through its research program, NOAA is determining the importance of fishery habitats, the effects of habitat loss on fishery resources, and the potential benefits of habitat restoration, enhancement, and mitigation.

ESTUARINE RESEARCH (cont'd)

CONTAMINANT EFFECTS. NOAA draws from a pool of research experts and facilities to examine the biological effects of pollutants such as synthetic organics (e.g., pesticides and PCBs), toxic metals, petroleum hydrocarbons, and excessive nutrients on living resources. NOAA examines not only the effects of contaminants on edible fish and shellfish, but also on food chain organisms.

NOAA also conducts programs to determine the public health significance of contaminants in fish and shellfish. These programs are designed to determine the kinds and levels of contaminants in tissues of fishery products and the chemical form and interaction of those contaminants.

CAPABILITIES	LEGISLATION	DESCRIPTION
RESEARCH	National Sea Grant College Program 33 U.S.C. 1121	Promote research related to ocean & coastal resources in all of the sub-categories listed under this heading.
PHYSICAL PROCESSES		
• Circulation Dynamics	National Ocean Survey 33 U.S.C. 883a, 883d	Conduct hydrologic and other surveys; research in geographical sciences.
• Chemical Transport	Marine Protection, Research and Sanctuaries Act 33 U.S.C. 1441 et seq.	Develop comprehensive research program on the long-range effects of pollution, including effects on the marine environment, fish and shellfish.
ECOSYSTEM DYNAMICS	Marine Protection, Research and Sanctuaries Act 33 U.S.C. 1441 et seq.	Develop comprehensive research program on the long-range effects of pollution, including effects on the marine environment, fish and shellfish.

CAPABILITIES	LEGISLATION	DESCRIPTION
RESEARCH		
LIVING RESOURCES		
• Life History	Magnuson Fishery Conservation and Management Act 16 U.S.C. 1851	National standards: conservation measures based on best scientific information.
	Anadromous Fisheries Conservation Act 16 U.S.C. 757	Conduct biological studies to conserve, develop, and enhance anadromous fish.
	Fish and Wildlife Act 16 U.S.C. 742d	Conduct investigations on: the production of fish and fish by-products; fishery statistics; availability and biological requirements of fish and wildlife resources (commercial and sport).
	Pacific Northwest Electric Power Planning and Conservation Act 16 U.S.C. 839b	Recommend measures to protect, mitigate and enhance fish and wildlife and their habitats affected by hydroelectric projects on the Columbia River and its tributaries.
• Disease	Agricultural Marketing Act 7 U.S.C. 1622(c)	Improve standards & quality of fish & shellfish products.

CAPABILITIES	LEGISLATION	DESCRIPTION
RESEARCH		
	Marine Protection, Research and Sanctuaries Act Title II 33 U.S.C. 1442	Monitor diseases in fish and shellfish.
	Fish and Wildlife Act 16 U.S.C. 742d	Conduct investigations on: the production of fish and fish by-products; fishery statistics; availability and biological requirements of fish and wildlife resources (commercial and sport).
• Aquaculture	National Aquaculture Act 16 U.S.C. 757(b)	Augment existing commercial and recreational products.
HABITAT RESOURCES		
• Fisheries-Habitat Interactions,	Magnuson Fishery Conservation and Management Act 16 U.S.C. 1851	National standards: conservation measures based on best scientific information.
• Habitat Alterations, Habitat Enhancement	Fish & Wildlife Coordination Act 16 U.S.C. 662(a)	Interagency consultation to give fish & wildlife resources equal consideration with other project purposes.

CAPABILITIES	LEGISLATION	DESCRIPTION
RESEARCH		
	Pacific Northwest Electric Power Planning and Conservation Act 16 U.S.C. 839b	Recommend measures to protect, mitigate and enhance fish and wildlife and their habitats affected by hydroelectric projects on the Columbia River and its tributaries.
	Federal Power Act 16 U.S.C. 811	Prescribe fishways during the construction of dams or diversions.
CONTAMINANT EFFECTS		
• Living Resources, Food Chain	National Ocean Pollution Planning Act 33 U.S.C. 1701 *et seq*.	Develop program for coordinated pollution research, development and monitoring. Coordinate research to support preservation and protection of estuaries of national significance.
	Marine Protection, Research and Sanctuaries Act 33 U.S.C. 1441 *et seq*.	Develop comprehensive research program on the long-range effects of pollution on biota, sediments, water column and fish.

CAPABILITIES	LEGISLATION	DESCRIPTION
RESEARCH		
	Acid Precipitation Act of 1980 42 U.S.C. 8902-3	Direct research into the effects of acid precipitation on fisheries, etc.
	Superfund 42 U.S.C. 9607(f), 9611(h);	Assess injury, destruction, or loss of natural resources in the coastal and marine environment caused by releases from facilities of hazardous substances.
	Clean Water Act 33 U.S.C. 1321	Assess injury, destruction, or loss of natural resources in the coastal and marine environment caused by discharge of oil from vessels or onshore or offshore facilities.
	Magnuson Fishery Conservation and Management Act 16 U.S.C. 1851	National standards: conservation measures based on best scientific information.
FISHERY UTILIZATION		
• Contaminants in Fish Products	Lacey Act 16 U.S.C. 3372	Unlawful to import, export, purchase, etc. fish and wildlife taken, possessed, transported, or sold in violation of any law of the United States or any state, foreign, or Indian tribal laws.

CAPABILITIES	LEGISLATION	DESCRIPTION
RESEARCH		
• Chemical Interactions Contamination of Shellfish	Food, Drug, & Cosmetic Act, Fair Packaging & Labeling Act 15 U.S.C. 1451-61	Mandatory requirements for food including fish and shellfish.
	Agricultural Marketing Act 7 U.S.C. 1622(c)	Improve standards & quality of fish & shellfish products.
	National Ocean Pollution Planning Act 33 U.S.C. 1701 *et seq*.	Develop program for coordinated pollution research, development & monitoring.
	Marine Protection, Research and Sanctuaries Act 33 U.S.C. 1442	Monitor diseases in fish and shellfish.

III. ESTUARINE MANAGEMENT

NOAA encourages wise management of the Nation's estuarine resources. NOAA administers programs for managing the Nation's marine fisheries, protecting valuable marine and estuarine habitats, and balancing coastal development and conservation activities. Additionally, NOAA provides expertise to Federal and state agencies that have management responsibilities in coastal areas.

LIVING RESOURCES. NOAA is authorized to manage living resources. These authorities extend to both finfish and shellfish as well as to endangered species and marine mammals. Because most species for which NOAA has management responsibility spend portions of their life cycle in the estuary, NOAA provides information and expertise to the States to assist them in their management programs. Through the Commercial Fisheries Research and Development Act and the Anadromous Fish Conservation Act, NOAA provides grants to states, universities, and other organizations to assess estuarine fisheries.

COASTAL RESOURCES. The Coastal Zone Management Act (CZMA) authorized the first national program to promote the wise use and protection of coastal land and water resources. This Act, administered by NOAA, provides funds, policy guidance, and technical assistance to coastal states to help them establish and maintain coastal zone management programs. The CZMA also provides for the designation of national estuarine research reserves, consisting of land and water areas that are managed as natural research laboratories for scientists and the public.

PUBLIC OUTREACH. Communication is an integral component of NOAA, and in particular, its National Sea Grant College Program. Universities and institutions funded by the program develop products for the public that communicate estuarine scientific findings and convey other information about estuaries. A film produced by the program in 1985, "The Chesapeake Bay - A Twilight Estuary," is a good example of Sea Grant's broad communication capabilities. The film provides an effective mechanism for informing the public of the stresses on the Chesapeake system and the role research has played in identifying those stresses. Publications providing advice to mariners and fishermen also are part of the program.

CAPABILITIES	LEGISLATION	DESCRIPTION
MANAGEMENT		Manages living resources and protected species; administers coastal zone management program; provides advice.
LIVING RESOURCES		
• Fisheries Management	Magnsuon Fishery Conservation and Management Act 16 U.S.C. 1812	Exclusive management authority for fish within the EEZ and anadromous species throughout migratory range.
• Interstate Fisheries Grants & Management	Anadromous Fisheries Conservation Act 16 U.S.C. 757	Department of Commerce and Interior, with states, conserve, develop, and enhance anadromous fishery resources.
• Protected Species Management	Marine Mammal Protection Act, 16 U.S.C. 1361 _et seq._	Responsibility for protecting and managing marine mammals under NOAA jurisdiction.
	Endangered Species Act 16 U.S.C. 1531 _et seq._	Responsibility for the management, conservation and recovery of endangered, and threatened species.

CAPABILITIES	LEGISLATION	DESCRIPTION
MANAGEMENT		
HABITAT RESOURCES		
	Fish and Wildlife Act 16 U.S.C. 742d _et_ _seq_.	Conduct investigations on: the production of fish and fish by-products; fishery statistics; availability and biological requirements of fish and wildlife resources (commercial and sport).
	Pacific Northwest Electric Power Planning and Conservation Act 16 U.S.C. 839b	Recommend measures to protect, mitigate and enhance fish and wildlife and their habitats from hydroelectric projects on the Columbia River and its tributaries.
	Federal Power Act 16 U.S.C. 811	Prescribe fishways during the construction of dams or diversions.
• Habitat Advisory Services & Resource Planning	Fish and Wildlife Coordination Act 16 U.S.C. 661-62	Interagency consultation to give fish and wildlife resources equal consideration with other project purposes.
	Clean Water Act 33 U.S.C. 1344(q)	Comment to Corps of Engineers on fish and habitat impacts of Corps dredge and fill permits.

CAPABILITIES	LEGISLATION	DESCRIPTION
MANAGEMENT		
COASTAL RESOURCES		
• Coastal Resources Program	Coastal Zone Management Act, 16 U.S.C. 1454	Enter into grants with coastal states to develop and implement a management program for the coastal zone.
	Marine Protection, Research and Sanctuaries Act 33 U.S.C. 1443	Cooperate with EPA to assess feasibility in coastal areas of regional plans for disposal of waste materials.
• National Estuarine Research Reserves	Coastal Zone Management Act 16 U.S.C. 1461	Designate representative estuarine areas as National Estuarine Reserves in which education, research and interpretive activities are conducted.
PUBLIC OUTREACH		
• Communication, Marine Advisory Service	National Sea Grant Program 33 U.S.C. 1121 _et seq_.	Conduct research, education, and advisory services for marine resources.

CAPABILITIES	LEGISLATION	DESCRIPTION
MANAGEMENT		
• Estuarine Education	National Sea Grant Program 33 U.S.C. 1121 et seq.	Conduct research, education, and advisory services for marine resources.
	Coastal Zone Management Act 16 U.S.C. 1461	Through natural field laboratories, provide estuarine research and public education programs.
ENFORCEMENT	Superfund 42 U.S.C. 9607(f), 9611(h)	Recover damages or seek funds from Superfund for natural resources subject to NOAA trusteeship injured, destroyed, or lost by releases of hazardous substances into the coastal and marine environment from a facility.
	Lacey Act 16 U.S.C. 3373	Provides for the Secretary to impose civil and criminal penalities and permits sanctions on any violation of the statute.

APPENDIX B

Federal Estuarine/Coastal Activities

FEDERAL ESTUARINE COASTAL ACTIVITIES

This section provides a brief summary of the major estuarine/coastal activities supported by federal agencies other than NOAA, including the Environmental Protection Agency (EPA), the U.S. Geological Survey (USGS), the Fish and Wildlife Service (FWS), and the Corps of Engineers (COE). While many other agencies have related programs, this section focuses on those perceived to have a central role in federal estuarine/coastal research and management.

ENVIRONMENTAL PROTECTION AGENCY (EPA)

The EPA assumes lead responsibility in the federal government for identifying, evaluating, and controlling environmental pollutants. Priority elements of the EPA mission are to reduce public exposure to harmful pollutants, protect sensitive ecosystems, regulate hazardous waste facilities, clean-up Superfund sites, and improve management of environmental regulatory programs. The Clean Water Act (CWA) (section 104(n)) requires the EPA to promote studies of the Nation's estuaries and to report every six years.

EPA's National Estuary Program was originally established in 1985 through a Congressional appropriation under the CWA. Estuaries included in the first year were Narragansett Bay, Buzzards Bay, Long Island Sound, and Puget Sound. San Francisco Bay and Albemarle/Pamlico Sound were added in 1986. The 1987 amendments to the CWA, the Water Quality Act of 1987, established the responsibility for the National Estuary Program in Sections 317 and 320. The Act instructs the Administrator of EPA to give priority consideration to eleven named estuaries, the six estuaries already participating and New York-New Jersery Harbor, Delaware Bay, Delaware Inland Bays, Sarasota Bay, and Galveston Bay. In addition, the Water Quality Act continued authorization for the Chesapeake Bay and Great Lakes Programs.

Program Description

EPA has substantial responsibilities in estuarine research, management and planning.

Research

a. Through its laboratories at Narragansett, Rhode Island and Newport, Oregon, EPA conducts research on marine, coastal, and estuarine water quality and marine processes.

EPA's Environmental Research Laboratory, located at Narragansett, responds mainly to legislative requirements of the CWA, the Marine Protection Research Sanctuaries Act, and to a lesser extent, the Toxic Substances Control Act, Resource Conservation and Recovery Act (RCRA), and Superfund legislation. The Laboratory is responsible for the following research: (1) estuarine and marine disposal and discharge of single contaminants or complex effluents, dredged materials, and other wastes; (2) water use designation and quality criteria for estuarine and marine water and sediment; and (3) environmental assessment of ocean discharges. These research program areas involve the development, evaluation, and application of techniques and test systems for measuring and predicting the transport, fate, and biological and ecosystem effects of wastes in estuarine and marine systems.

b. Management

Through the Water Quality Act, EPA is conducting management-oriented estuarine restoration and protection programs in seven major estuaries around the country.

The EPA's National Estuary Program is designed to take advantage of existing authorities within the Water Quality Act, other federal statutes, and state and local legislative authorities for point and non-point sources to adequately protect the Nation's estuaries. The EPA program emphasizes the need to focus and integrate the efforts of existing pollution abatement and control monies. The goals of the program are to: (1) increase public understanding of the complexities of a particular estuary; (2) increase understanding of the need for and benefit of area-wide or basin planning, management and pollution control; (3) develop plans for the control of pollutant loadings; (4) encourage acceptance of the public and private costs of increased pollutant abatement; (5) transfer technical assistance and scientific expertise to State and local governments to implement action plans; and (6) protect and restore water quality and living resources to the estuary.

c. Planning

Near Coastal Waters Strategic Plan

EPA has begun implementing its Near Coastal Waters Strategic Plan, a long-term planning strategy designed to improve EPA's ability to manage near coastal water environmental quality. The term "near coastal waters" is defined as inland waters to the head of the tide, the territorial seas, and the contiguous zone including areas of greater distance where necessary to protect coastal barrier islands and the mouths of certain estuaries. The Great Lakes are also included. The implementation plan will address five major national environmental problems: toxic contamination; eutrophication; pathogens; habitat loss/alteration; and changes in living resources. The plan will incorporate the following types of tools: regulatory; research and data collection; innovative management techniques; institutional changes; intra- and interagency coordination; technology transfer; and public outreach.

DEPARTMENT OF THE INTERIOR

1. U.S Geological Survey (USGS)

The USGS is responsible for the classification of public lands, and examination of the geological structure, mineral resources, and products of the national domain. Over the years, its mission has expanded to include hydrological investigations of water in streams and underground. Some of this work is conducted in estuaries or at the fall line for waters flowing into estuaries. For example, the USGS is examining the influence of different land uses on the water quality of the streams that flow into the Susquehanna River.

Program Description

The Water Resources Division of the USGS provides hydrological data on surface and ground water and conducts research to assure competent hydrologic investigations. Programs of particular interest include long-term operation of down-stream gages on major rivers and streams, site-specific investigations of estuarine circulation, geochemistry, and ecology. Much of this work is conducted in the Potomac River, where hydrodynamic and geochemical processes, as well as long-term changes in wetlands ecology are being studied, and the San Francisco Bay, where the USGS is researching processes that influence water and sediment chemistry.

2. U.S. Fish and Wildlife Service (FWS)

The FWS has general responsibility for maintaining the fish and wildlife resources in the United States and providing public access to these resources. Its functions include responsibility for fish and wildlife resources and habitats of national interest through research, management, and technical assistance to other federal and non-governmental agencies.

Program Description

The operations of the FWS include those conducted in the coastal zone, the contiguous lands, and the waters that flow into the zone. Major FWS programs involving coastal issues include permit review and resource planning; land acquisition and habitat management (through refuges and easements); management of migratory birds, anadromous fish and endangered species; and a broad research activity addressing causes and effects of habitat change and coastal contaminants. These programs provide for the collection, synthesis, and interpretation of diverse information on species, populations, and habitats that is assembled, analyzed, and applied for management purposes.

As examples of FWS estuarine studies, important research in the Northeast Region includes documentation of coastal wetland changes, migratory waterfowl distributions, and the effects of hunting pressures. In addition, the FWS conducts special studies on striped bass and American shad; damage to estuarine systems, such as the Chesapeake Bay, from point and non-point discharges; and the effects of development activities on important fish and shellfish breeding grounds and waterfowl habitat.

In the Southeast Region, the FWS conducts research on endangered species, such as the Florida Manatee and various coastal birds and sea turtles. For example, FWS has initiated field studies to evaluate the habitat requirements of the Manatee. Additionally, FWS personnel are examining the effects of peat mining in coastal areas on coastal fish and wildlife.

Major research in the Texas Gulf Coastal area is being conducted on the impact of soil desposition on bays and channels, largely through desposition of dredged materials dumped in shallow estuarine waters and from contaminated agricultural runoff. Studies of wetland losses are being aided by Geographic Information Systems (GIS). The GIS technology that documented wetland losses of 80 percent in Louisiana have resulted in public recognition of the potential long-term effects of coastal change on fish and wildlife populations. GIS has become a major decisionmaking tool for predicting potential impacts of development activities of habitats. Prototype methodologies are also being developed to assess cumulative impacts.

Primary research in the Southwest Region focuses on the restoration of fish and wildlife to the San Francisco Bay area and the study of impacts caused by diversions and diked systems, and management and restoration of the endangered southern sea otter. Kesterson National Wildlife Refuge research on selenium and other problems is being guided by an Interagency Technical Coordination Committee comprised of state, other federal agencies, and FWS personnel.

Contaminant monitoring on the Great Lakes Region includes examination of fish tumors, research into the causes of the declining lake trout populations, and the fate and effects of contaminated sediments. In addition, research efforts focus on the impacts of power plant discharges to the Lake Erie system and biota.

In Alaska, the FWS is examining the impact of North Slope oil and gas development on migratory fish. It is also developing techniques for the genetic identification of Alaskan and Canadian stocks of salmonids for fisheries managment purposes.

Finally, most of the development of the analytical tools for estuarine planning and management is centered at the National Wetlands Research Center (NWRC) formally National Coastal Ecosystems Team of Slidell, Louisiana. Principal NWRC activities are: (1) development of habitat-descriptive methods - their validation and transfer to users; (2) the development of community and species "profiles" to assist with site-specific and regional planning; and (3) special issue studies for FWS operations.

ARMY CORPS OF ENGINEERS (COE)

The COE has broad responsibilities in inland waters and near-shore areas stemming primarily from the Rivers and Harbors Act, the CWA, the Water Resources Development Act, and the Marine Protection, Research and Sanctuaries Act. These laws provide the COE with the authority to maintain navigable waterways, and to issue permits for the transportation of dredged material for ocean dumping and for the discharge of dredged or fill material into the waters of the United States.

Program Description

a. Coastal Engineering Program: The COE missions require coastal engineering expertise in the design, construction, operation, and maintenance of three general types of projects or facilities in and near the surf zones of the U.S oceanic and Great Lakes shores: (1) habors for small craft for commercial and recreational fishing; (2) harbors for large, ocean-going vessels for coastal and international commerce; and (3) shore and beach restoration, protection, and stabilization.

   Research activities include developing methods for predicting sediment transport and shoaling, improving methods to collect littoral data, and improving wave estimation to assess physical factors in beach erosion and nourishment.

b. Flood Control and Navigation Program: This program is designed to improve cost-effectiveness of flood control programs and navigation-related activities including channel or canal, construction and maintenance.

   Research includes developing: (1) improved methods for dredging; (2) more effective sediment traps; and (3) estuarine-specific physical models (numerical and physical) to assist project design and maintenance.

c. Environmental Quality Program: Projects associated with this program focus on determining the impact of COE water resources projects on the environment. In particular, research examines methods to mitigate shore-line erosion, identifies the ecological effects of rubble structures, and determines the effects of channels and jetties on fish and shellfish migration.

d. Wetlands Project: Priority wetland research needs have been identified in two major areas: (1) development of techniques to identify and delineate wetlands and (2) assessment and quantification of wetland values for use in evaluation of permit activities. These studies include developing regional procedures in identifying and delineating wetlands during the fall and winter seasons, and evaluating plant tolerance to inundation and saturated soil conditions.

e. Dredged Material Research Development, and Monitoring Programs: Under Section 404 of the CWA and Section 103 of the Ocean Dumping Act, the COE is responsible for permitting the placement of dredged and fill material in the Nation's waterways and the transportation of dredged material for disposal in the oceans. At present, the COE receives more than 10,000 permit applications annually under Sections 404 and 103. These permits must comply with criteria and the COE's long-term effects of dredging operations provides the information for the criteria.

   Studies are designed to: (1) determine bioaccumulation and biomagnification in the aquatic environment; (2) develop procedures to reduce adverse impacts; (3) develop upland plant and animal bioassays procedures; (4) develop or improve techniques for predicting contaminant concentrations in the effluent from these sites; and (5) improve methods for leachate prediction and control. The COE is also examining procedures to identify and assess the elements necessary for a long-term strategy for dredged material disposal, and to provide user guidance to permit effective disposal.

f. Dredged Contaminated Sediments Project: To mitigate the impacts of dredging contaminated sediments, the COE is collecting data on the re-suspension of sediments and contaminants. The COE is also developing guidelines for dredging highly contaminated sediments. The COE is conducting a demonstration project at Indiana Harbor-Great Lakes, where innovate foreign equipment will be used in a pilot demonstration for PCB sediments.

g. Satellite and Surveying Application Program: The Satellite and Surveying Application Program develops and applies new technology for surveying and satellite remote sensing and positioning interpretation techniques, data handling, and assessing satellite-acquired data for water resource planning and management models. Research activities in the current program include using satellite data for detecting and mapping areas wetlands, applying satellite data to solve coastal engineering problems, and evaluating remote sensing techniques to monitor changes in aquatic vegetation in coastal and estuarine environments.

APPENDIX C

Workshop Summaries

ESTUARINE RESEARCH WORKSHOP SUMMARY
June 4-5, 1986
Raleigh, North Carolina

NOAA conducts research in the Nation's estuaries through a network of NOAA laboratories and Sea Grant universities. In order to focus its research and develop NOAA's Estuarine Plan, scientists from Sea Grant universities and the NOAA laboratories met to identify major research needs in estuaries. The issues identified by this team of researchers were organized under five broad categories.

1. Coupling of Primary and Secondary Productivity
   - Major energy pathways
   - Role of natural processes and human activities
2. Water Management and Estuarine Productivity
   - Effect on biological structure and function
   - Relationship between forcing functions and hydrologic characteristics
3. Sediment Management and Estuarine Productivity
   - Role of organisms in sedimentation
   - Role and impact of episodic events on sediment
4. Habitat Requirement for Living Marine Resources
   - Major processes controlling productivity
   - Recruitment and fisheries productivity relationship
5. Input of Nutrients and other Contaminants to the Estuaries
   - Bioaccumulation and effects
   - External nutrient loading and internal nutrient cycling

List of Participants

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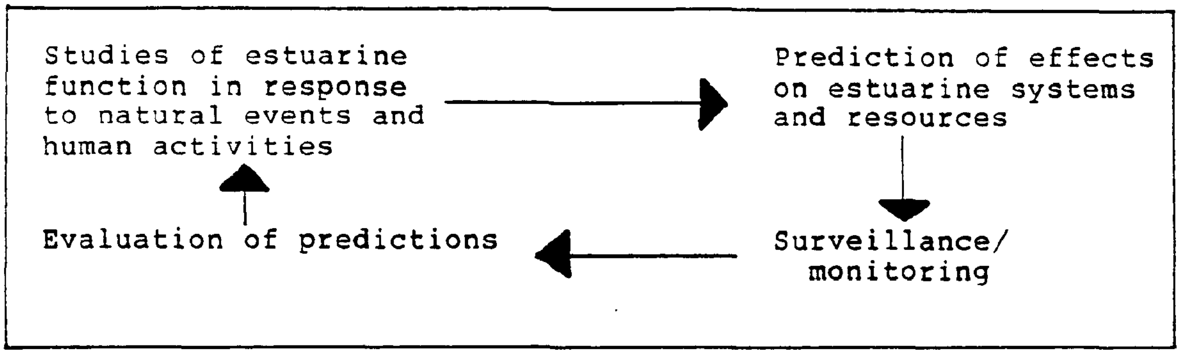
*Provided written input

RESEARCH STRATEGIES NEEDED TO MANAGE
THE NATION'S ESTUARIES

Because of the enormous importance of estuaries to society, resulting from the numerous and varied purposes they serve and because of the stressed nature of many estuaries resulting from these multiple and conflicting uses, it is not surprising that society has demanded that government direct its attention at managing and, when necessary, rehabilitating these valuable natural resources. It is also not surprising that this attention has been directed at developing strategies to stop pollution, safeguard habitats for critical species and restore the aesthetic values and living resources of the estuaries. The responses of our elected officials at all levels to citizen demand for action and the estuarine programs which have been generated by our federal and state agencies responsible for protecting and managing our estuaries have been laudable. Most of these programs, however, have been only marginally effective in improving our ability to manage because not enough attention has been paid to fundamental research to provide the knowledge necessary for effective management programs. Research information often is not summarized in a manner to be properly applied to management problems.

The management of these most complex and variable segments of the world ocean is a formidable job. Those with whom we charge this responsibility must be provided access to the best scientific and technical information available. Management is a dynamic process; one which depends upon timely and accurate information. With greater knowledge, the limits on what is possible are extended and the likelihood of making appropriate and effective management decisions is increased.

In an ideal world, estuarine management would be based on a comprehensive understanding of ecosystem functioning. Estuarine managers would be able to predict, more often than not, how coastal systems respond to specific suites of environmental conditions. While such understanding is not within our grasp as yet, a directed effort to move towards improved prediction should form the framework for NOAA's estuarine research. In this regard, estuarine studies must be seen as components of an iterative process:



Studies of estuarine function in response to natural events and human activities. Prediction of effects on estuarine systems and resources. Surveillance/monitoring. Evaluation of predictions.

NOAA conducts research in the nation's estuaries mainly through a network of Sea Grant universities, NOAA laboratories and by grants and contracts. In order to focus research efforts into a national program, leading estuarine scientists from the network have identified the essential research needs. Nine critical questions were identified by the team of scientists, representing Sea Grant universities and NOAA laboratories, which fall under the following broad management problems:

- o Ecosystem Coupling and Productivity
- o Physical Forcing Functions in Estuaries
- o Roles of Anthropogenic Inputs

Ecosystem Coupling and Productivity

Research Questions:

- o What are the major energy pathways and how are they affected by natural and human activities?
- o What processes control variability in productivity?
- o What is the relationship between recruitment and fisheries productivity?

Estuarine ecosystems are characterized by high levels of primary and secondary productivity. The connection between high primary productivity and the quality and magnitude of secondary productivity is uncertain and the question of the importance and ecological efficiency of individual food chain pathways remains unresolved. Food chains in estuarine ecosystems are connected quantitatively and qualitatively and it is the goal of research to understand the relationships between the quantity and quality of biomass at one producer level and the quantity and quality of biomass at the next level.

Many of society's activities have decreased the transfer efficiency of energy from lower to high trophic levels. The major impacts of human activities on energy pathways come through habitat alterations from the addition of waste effluents and agricultural and urban runoff. Food chains have been affected by introduced toxic substances and nutrient enrichment causing blooms which increase shading and deplete oxygen supplies. Along with an understanding of the fundamental relationships within estuarine food webs, we need to know such things as how wetland destruction or habitat alteration affect fisheries production, how various materials (e.g. toxics) are transferred through the food chain, how blue-green algae produced in some estuaries impacts secondary consumers, and whether detritus is a major source of carbon.

An estuary's primary role traditionally has been seen as that of a nursery for commercially and recreationally important fish and shellfish species. However, it has been observed that some estuaries produce far more fish than others and it is not clear how essential that role is. Understanding the role that estuarine habitat plays and the impacts of anthropogenic inputs on the quantity of fish produced will provide a key to effective fisheries management.

To learn what makes one estuary more productive than another, scientists must address questions about habitat selection, species migration, species residence times, food availability, circulation and exchange patterns, habitat quality and the effects of environmental variations on survival, growth and movement of fish and shellfish. Because much of the habitat value in estuaries comes as nursery areas for species spawned elsewhere, recruitment of the young must be crucial to the development of fisheries production. Although considerable work has been done in this area, we still do not know the nature of the relationship between recruitment (how animals arrive and the importance of numbers) and fisheries productivity. Answers will help resource managers establish criteria to protect the estuarine characteristics that provide answers to critical questions of whether improved and enlarged nursery habitat will enhance fisheries production in our Nation's estuaries.

<u>Physical Forcing Functions in Estuaries</u>

Research Questions:

- How do alterations in natural water inflow patterns affect biological structure and function?

- What is the relationship between major forcing functions and hydrologic characteristics?

- What is the role and impact of episodic events on sedimentation?

An important problem facing our Nation today is the allocation of freshwater resources. As municipal, commercial, industrial, agricultural and recreational demands for water increase, the availability of water to downstream estuaries decreased or is or navigation also alters the freshwater supply to estuaries. The prospects of altered precipitation patterns as a result of global climate changes predicted during the next century may also affect the amount of fresh water received by our estuaries. Changing land uses around estuaries and near the upstream tributaries affect the quantity, quality and timing of freshwater inflows. Since by definition estuaries involve the inflow and mixing of fresh water and salt water, any variation can cause significant changes in estuarine productivity. The interrelationship between freshwater inflow and primary and secondary production in the estuaries poses a prime research question. Water flow is a major factor controlling the aging of an estuary.

One of the crucial questions concerning water management is the need to know the quantitative relationship between freshwater inflow and fisheries production in specific estuaries and regional groups of estuaries. We need to determine how much freshwater inflow is too much or too little on a seasonal or annual basis; e.g., the factors that control the response and recovery of an estuary's physical and biological system to large changes in water input are not know. Cycles in freshwater inflow may create permanent changes to higher levels of biota and contribute to the variability of spawning activities. On the ocean side of the estuary, coastal upwelling represents a major intrusion of water with different temperature and nutrient characteristics that may or may not stimulate an estuary's productivity. We need to develop a better understanding of physical forces for different types of estuarine systems in order to manage for optimum conditions of salinity, nutrient availability, larval recruitment and waste dilution.

The rate and variability of processes mediating the release and exchange of materials from sediments to the overlying waters are virtually unknown. Episodic events such as hurricanes and floods may be influential in determining those parameters. A major controlling factor is the chemistry of sediments and their interstitial waters; these processes can be drastically altered by catastrophic events such as storms or sediment slumping.

Role of Anthropogenic Inputs

Research Questions

- To what extent do organisms affect sedimentation?
- What is the relationship between bioaccumulation and effects?
- What is the relationship between external nutrient loading and internal nutrient cycling?

Sediment quantity and quality can affect estuarine productivity. In addition, man's activities in the watershed affect sed iment processes such as the inputs of sediment, their rates of accumulation, turbidity and their contaminant loadings. To better manage the impacts of sediment processes, researchers need to examine the rates of accumulation and the changes in sediment composition between where the sediment enters the estuary and where it accumulates. We also need to better describe the processes that control the movement of fine-grained sediments and the absorption and desorption of contaminants. The capability should also be developed to predict the relationship between the patterns and rates of sediment accumulation and habitat type for a range of environmental conditions.

The transport of most chemical species of concern to and through an estuary is in the particulate phase. The bio-availability of this material to filter feeders and to deposit feeders is controlled by the strengths of the contaminant binding forces and chemistry of the guts or organisms through which it passes. In areas of high estuarine productivity filter feeding organisms may control most of the sedimentation by bio-packaging of suspended particulate matter. Biological repackaging may control the downward flux of hydrophobic chemicals, uptake from the sediments and sediment accumulation rate. Therefore, the dynamics of population and productivity may be extremely influential in determining the sedimentation rate and the rate of accumulation of sediment-bound contaminants. The degree to which sediments bind, and thus "detoxify", pollutants also must be determined.

Observations indicate that nutrient enrichment and toxic contamination problems in estuaries are increasing. More people are living near our Nation's estuaries and increases in their use of inorganic fertilizers, conversion of wetland to urban and agricultural use, waste disposal, storm water runoff and the increased use of a large number of synthetic chemicals may overwhelm the estuary's ability to act as a nutrient and sediment sump, thereby increasing estuarine nutrient and contaminant levels. We do not yet understand the multiple relationships among nutrient inputs, recycling and biological production; and research is needed to test how estuarine ecosystems respond to nutrient input in terms of recycling and nutrient removal. The relationship of new nutrient supplies to recycled nutrients is critical to understanding biological responses which lead to eutrophication and serious oxygen depletion (hypoxia).

Scientists need to study the ultimate fate of a host of synthetic organic chemicals and metals found in the estuary. The relationship between biological exposure and effects is specific to the receiving species. In each case, meaningful effects must be defined and the exposure which causes them measured. With considerations of appropriate environmental controls and synergisms such effects can not be predicted using existing capabilities. Variations in sensitivity at different life stages, incubation time, water uptake, and feeding experiences all contribute to variability and exposure to contaminants.

ESTUARINE MANAGEMENT WORKSHOP SUMMARY
June 25-26, 1986
Washington, D.C.

NOAA administers programs for managing the Nation's marine fisheries, protecting valuable marine and estuarine habitats, and balancing coastal development and conservation activities. NOAA also provides expertise to federal and state agencies that have management responsibility in coastal areas. NOAA and Sea Grant personnel in estuarine management and information related programs met with state managers familiar with fisheries, water quality and coastal zone management disciplines to identify national estuarine management and information needs for the NOAA Estuarine Plan. The participants identified the following resource and policy categories relating to estuarine management.

Resource Issues

1. Freshwater Inflow

   - Quantitative models for impact assessment
   - Trends and impacts of flow alteration

2. Habitat

   - Relation and importance of habitat to fisheries and ecosystem integrity
   - Evaluation of habitat restoration and rehabilitation techniques

3. Toxics

   - Quality, significance and appropriate use of toxics data
   - Pathways and effects of toxics

4. Nutrients

   - Loading of nutrients from natural and anthropogenic sources
   - Nutrient transfer models

5. Pathogens

   - Measurement and monitoring techniques
   - Effects assessments

7. Land Use

- Measurement techniques to assess the impact of land use
- Impacts/effects on the physical environment

Policy Issues

1. Institutional Roles and Relations

Issues

- Internal Coordination
- External Coordination
- Leadership

Recommendations

- Elevate Estuarine Programs Office
- Establish Interagency Work Group
- Develop NOAA-wide policy statement
- Establish National Estuarine Research Center

2. Information and Public Understanding

Issues

- Target information for users
- Information synthesis and dissemination

Recommendation

- Establish Estuarine Information and Dissemination Center

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Estuarine Management Work Group Meeting
June 25-26
Washington, D. C.

On June 25-26, 1986 representatives from NOAA met with individuals from state, academic and private organizations to identify major estuarine issues from a manager's perspective. The meeting was held in conjunction with an estuarine research work group to provide information needed in the development of a NOAA-wide Estuarine Plan.

Following introductory remarks and an overview presentation of NOAA's program activities in estuaries, the management work group identified issues relating to resource information, program coordination and direction. The following summary outlines the major issues and themes identified at the meeting.

Resource Issues

The meeting participants identified eight categories of management concern and general resource questions for each category. The list of questions was later refined to identify key concerns in each category. The following summary characterizes the scope of the discussions and identifies the key concerns as recognized by the group.

Physical Alteration

The commercial and aesthetic amenities of the estuarine environment continue to attract intense residential and industrial development. The resultant physical alternation of estuarine features to accommodate this growth stresses the vitality and resilience of an estuary to support healthy fish and shellfish populations.

Consistent comprehensive information on the status and value of the estuarine environment is needed to identify habitats most in need of protection. Managers need data on the trends and rate of loss of these habitats. This information must distinguish between the losses that can be controlled (anthropogenic) and those which occur naturally.

Second, beyond characterizing the nature of the resource and rate of losses, management makes decisions on individual development proposals. Determining the cumulative effect on the estuary of existing and future permit decisions is the least tractable but potentially most significant aspect of estuarine management. How will these changes affect flow regime, transport mechanisms, commercially important species, and the broader ecosystem? Beyond the adjacent estuarine shoreline, how do changes in land use in upland portions of the watershed effect the health of the system. Finally, once the physical alteration has occurred, what alternatives for mitigation and restoration are available to managers? Can dredged material be used to enhance fishery habitat? What areas should be avoided as disposal sites? Better information on the wide range of mitigation techniques, costs and benefits, feasibility and overall usefulness is needed.

Key issue: Understanding the functional importance of habitat to fisheries production and the ecosystem.

The group recommended that information be developed to assess the value of various types of habitat, describing tangible and intangible benefits in as quantifiable a manner as possible. The values of these habitats must be communicated effectively to influence permit decisions. Useful tools in this effort would be a comprehensive data base on wetlands and an index describing the benefits and values of various types of habitat to fisheries production.

Freshwater Inflow

Estuaries are defined by the volume and mixing of fresh and saline waters. Reductions or other modifications in freshwater inflow have been shown to cause significant changes in productivity and species composition. The reduction in freshwater inflow from dams and diversions of inland rivers as streams is a major concern. Information on the trends in water diversion and consumption is needed.

In assessing the consequences of proposed diversions, managers need better information on the effects of freshwater flow reductions to biological populations and long-term ecosystem productivity. Those effects must be defined clearly in both economic and political terms.

Key Issue: Better predictive tools primarily in the form of mathematical models are needed to determine the potential consequences of freshwater flow modifications. NOAA and the USGS should develop strategies and research programs that will result in useful guidelines for water management.

Toxics

Toxic pollutants both inorganic and organic affect the quality and productivity of the estuarine environment. Information needs have been expressed for all facets of the toxics issue.

First, better identification of the sources of toxic contaminants both point and non-point is needed. In addition to the geographic location of input, data is needed on the type and amount of the various constituents that comprise the loadings. Once in the estuary information is need on the transport of these materials, their dispersion and transformation characteristics and the eventual deposition sites within the estuary. These equations must also indicate the rates and locations of resuspension in the water column through biological or geochemical pathways.

Second, research and information on the effects of toxic substances to biological systems was recognized as crucial to informed management decisions. From a biological perspective, assessment of the cumulative effects over time of doses of a variety of contaminants should be considered. How do these chemicals interact in both a synergistic and additive context and what kinds of sublethal, chronic effects can be predicted for the diversity, fecundity and health of fishery resources? Research should particularly target the effects on juvenile stages of fish populations and their supporting seagrass habitats. This is a critical development stage for which information is noticeably lacking. The biological and chemical information on toxic effects must be translated into economic terms to consider the consequences to harvest and product marketability.

Finally, managers need better predictive and assessment tools to improve the quality of decisions relating to toxics. What are the best and most cost-effective methods to chemically identify toxicants? Are basal metabolic procedures efficient in gauging effects and what species are most appropriate as bio-indicators. With the wide range of procedures for assessing toxic contamination, it is difficult for management to make consistent decisions on the nature and importance of the threat to the environment. This leads to the concern many suggested was fundamental to the toxics issue; i.e., the quality and significance of information available on toxic contamination.

Key Issue: Quality and significance of data on toxicants. Information on toxics should be intercalibrated more widely among laboratories. NOAA should work to expand its quality assurance and quality control programs beyond its own contractors to other universities and state laboratories. In doing this NOAA needs to develop consensus on the best tools and methods available to measure toxics. Special emphasis should be placed on how best to interpret information on the use of biological indicators of toxic contamination. The research community must make clear the limits of the data developed on toxicants and its appropriate use for decisionmakers. Understanding the natural versus anthropogenic contributions to the toxics problem is central to the portrayal of the data.

Existing management programs specifically the NPDES program can be improved significantly. Currently, information gathered through this permit system provides only a rough measure of toxic inputs to estuaries. Information on biological oxygen demand and total suspended solids is collected but little else is available. Strengthening of the permit system is necessary to better understand the contaminant loads to the system.

Nutrients

Like toxics, information is needed on the sources, loading and resuspension rates of nutrients to estuarine systems. Because nutrients such as nitrogen and phosphorus are naturally occurring and fundamental components of estuarine systems, it is especially important to distinguish between the nutrient inputs than can be controlled and those that contribute to the natural biological aging of the system. Additional investigations of the role and relation of nutrient loading to species diversity and estuarine food web structure should be conducted and the results effectively communicated to management.

Management tools available to control nutrient input bear improvement, particularly for non-point sources. Predictive models describing effects of alternative nutrient control strategies are promising but require better data on basic estuarine processes.

Key Issue: Distinguishing natural and anthropogenic nutrient contributions.

Research is needed on methods to screen natural versus anthropogenic inputs of nutrients and the vulnerability of biological systems to accommodate these loadings. Information is lacking on how nutrients are cycled through estuarine systems and the role of sediments as sinks and sources of nutrient loads.

Particularly relevant is the role of large episodic events such as hurricanes in the aging and nutrient enrichment of estuarine systems. Finally, how do we translate this information into effective regulatory programs that provide demonstrable results that legislatures can understand and support.

Habitat Rehabilitation

While there is increased emphasis through federal and state regulatory programs to compensate for habitat losses, little is known or understood about the technical problems associated with creating or rehabilitating various habitat types. A comprehensive assessment of habitat rehabilitation efforts should be considered. Such assessment should describe the criteria to be used to gauge the success and effectiveness of rehabilitation projects, consider the value of natural versus man-made habitats and propose criteria for selecting the habitat types and conditions that are most amenable to successful rehabilitation.

The administrative aspects of habitat rehabilitation should also be examined to address questions of the role of government and private sector in the permitting, design, development and monitoring of habitat sites. Information is also needed on the effectiveness of broad habitat program concepts such as mitigation banking to consider whether these strategies have the unintentional effect of encouraging higher rates of wetland destruction and development.

Key Issue: Does habitat mitigation work?

Research and information on the habitat mitigation efforts and successes should be assembled and disseminated. Study is needed on the long-term benefits of habitat rehabilitation efforts and weighed against habitat protection alternatives. This analysis should include the comparative costs of rehabilitation versus protection, the values of restored habitats, the kinds of tradeoff in quality and productivity associated with rehabilitation, and the enforcement aspects of ensuring that new habitat is properly created and maintained.

Overfishing

A healthy, productive fishery resource is a basic indicator of estuarine quality. Declines in fishery harvest can be attributed to water quality and habitat management practices. However, it is important not to overlook the effect of simply harvesting fish and shellfish stocks at a rate that exceeds the capacity of the estuary's biological systems. Management decisions on allowable fishery harvests are often based on uncertain scientific information and political criteria.

Basic, consistent data are needed on the status and trends of estuarine-dependent stocks. Research should further attempt to define the causes and consequences of changes in fishery stocks as a result of natural variability. This kind of research is truly interdisciplinary and requires contributions from many facets of estuarine science. It is important that managers have the best possible information on the man-made versus natural causes of stock variability.

From the regulatory perspective, new mechanisms and procedures should be explored to more efficiently manage fishery harvests. It is particularly important to consider the problems associated with interjurisdictional management of estuarine species. There is little consensus on the effectiveness of existing fishery management practices such as net size requirements, limited entry, size restrictions, etc. Comprehensive study of this issue would be useful. Such a study should also consider the use of fish hatcheries to support higher fishery productivity. What effects do hatchery raised stocks have on the genetic variability of the resource, resistance to disease and implications for continued poor management practices? The fundamental question concerning this issue is what effect does overfishing have on the sustained productivity of the estuarine environment.

Key Issue: Ecosystem impact of overfishing.

When certain stocks are overharvested, both subtle and obvious effects occur throughout the ecosystem. Information on the implications of overfishing to other levels of the food chain and other important commercial stocks is poorly defined. The development of predictive models that address the ecosystem implications of overfishing would improve management decisions. State and Federal managers should place greater emphasis on ecosystem interaction and focus management plans on a multi- rather than single species basis.

Pathogens

Disease of fish and shellfish from pathogenic agents has important consequences in terms of direct economic losses, marketability and consumer perceptions. Managers need better information on the movement and fate of pathogens through the estuarine environment as well as the trends in closures of areas for harvest nationwide. Once areas have been closed, little guidance is available on how best to manage these areas. It would be useful if basic criteria and standards were developed for monitoring conditions and regulating uses of these areas.

Restoration of these areas for commercial and recreational use can be a costly and lengthy process. Better information on clean-up techniques and costs of alternatives such as relaying shellfish for depuration should be developed. In the movement of products from the estuary to market, management must ensure that public health is protected. Better methods for measuring and identifying pathogens in fishery products are needed. This information must be combined with reliable assessments of the potential risk to human health from product consumption.

Key Issue

Develop better methods for measuring/monitoring pathogens and their effects.

Rapid, inexpensive methods for detecting pathogens in water and shellfish tissue are needed. These methods should provide a consistent basis for decisions on closure of areas for harvest. Every attempt should be made to develop standards for closure that can be implemented on a state-by-state and county level basis.

Land Use

The shape and form of coastal development is the dominant influence on the productivity and health of an estuary. Each use commercial, residential, agricultural, recreational and industrial influences and alters the estuarine environment in distinctive ways. Land use patterns around estuaries change in dynamic fashion. Reliable information systems that provide data on the current and anticipated uses in the estuarine coastal zone are important management tools that require more sophisticated development. As land use changes from rural to more urbanized, decisions are made that weigh the value of estuarine resource against the economic benefits of proposed development. The economic assessment process continues to struggle with criteria for valuing natural resources. Continued attention should focus on proper measurement of the costs and impacts associated with land use decisions in the estuarine environment. The subtle but significant effects of development are poorly measured. Problems such as long-term changes to fisheries productivity and estuarine circulation require refined modeling capabilities.

Gauging the cumulative effects of changing development patterns is a central management function. When the potential effects of development become evident, managers must consider the most appropriate mix of controls and strategies to minimize unnecessary harm to the environment.

Questions that deserve greater attention include how best to establish a cost-effective balance between point and non-point pollutant loadings, how to weigh coastal development proposals with alternative upland uses, how to best fit available regulatory tools to particular development proposals, do planning strategies such as special area management plans (SAMP) work, and finally what are most effective means to persuade decisionmakers to adopt particular management strategies?

Key Issue

How to predict the effect of land use change on estuarine water quality.

Concern was expressed that a wide array of methods are used to characterize estuaries and the adjacent land uses. There should be uniform and consistent methods developed to measure the basic features and land use patterns of estuaries. The participants stressed the important of developing models to help predict ecosystem changes in land use patterns. Such models need to be longitudinal, demographically based and clearly link land use changes with changes in estuarine quality. To complement the system it would be useful if a compilation of the important regulatory tools and strategies from local, regional and national perspectives were prepared. A resource assessment system and regulatory analysis would provide needed support for managers information and control strategy needs. Information should also be developed that catalogs the potential effect of different kinds of development on the major environmental components of an estuary. It is particularly important to consider the changes in rates of sedimentation and sediment type that will result from various projects. Regional differences in estuaries must also be considered in these analyses. The type of terrain, vegetation, circulation and degree of development must be considered in management deliberation. While development patterns and the capability of each estuary to sustain change will vary, management would benefit from the development of broad principles and national assessment tools that would establish a framework for subsequent site-specific management decisions.

Institutional/Policy Issues

On the second day of the workshop participants divided into three groups to consider issues of an institutional or policy nature that cut across the various resource-related concerns expressed above.

Information

The synthesis, packaging and dissemination of NOAA's information-related activities were major areas of concern. Managers frequently expressed the need to have information on basic estuarine characteristics assembled and synthesized in a manner that understandable and easily retrieved. It was recognized that NOAA maintains the bulk of estuarine environmental data available from a national level and that programs are underway to organize that information in a form useful for decision-making. However, this information is still difficult to retrieve and not always responsive to the time frames necessary for management.

It was therefore recommended that a discrete estuarine information applications group be established which would be familiar with the limitations and uses of the NOAA data, while also responsive to the needs of external users.

Dissemination of information on NOAA's estuarine-related products and services could also be improved. The concern was expressed that important interest groups, users and the Congress are not getting the right kind of data or level of information synthesis be a specific component in each major NOAA estuarine-related program. Mechanisms should be developed to distribute information to both technical and non-technical groups. An annotated estuarine bibliography of NOAA products may be useful in this regard. In this process it was urged that the users and producers of information plan together in the early stages of product development to ensure that the results of the effort are applied efficiently.

Program Coordination and Direction

NOAA has an exceedingly diverse array of estuarine-related programs, but there is little uniformity in the priority and level of effort devoted to estuarine concerns within the agency. This problem is manifest both is a geographic sense among regional offices and by the scientific and management disciplines represented in the agency.

The participants recommended that as a first step, NOAA develop a policy statement that describes the agency mission and commitment to estuaries. That statement should emphasize that NOAA's role is in the development of an agenda for addressing estuarine problems and needs from the national perspective. NOAA should place a higher priority among all its components on estuarine protection. This would be supported by 1) adopting a stronger, more active role in estuarine research and management; 2) improving contacts with other federal agencies and programs; 3) participating in the development of estuarine related-policies at other federal agencies, and; 4) using existing NOAA/coastal State mechanisms to provide guidance and information on the progress, direction and cooperative opportunities provided by NOAA's estuarine programs.

In assuming a stronger leadership role NOAA should emphasize development of programs and products that anticipate long-term needs to predict change and cumulative effects. Predictive tools such as biological indicators of degraded environments, criteria and standards, permitting, policy and resource management strategies and models represent the kinds of products managers consider most appropriate for development at the federal level. NOAA should consider establishing an Estuarine Prediction Center to develop, synthesize and distribute NOAA's estuarine services.

APPENDIX D

Regional Summaries

APPENDIX D

Regional Summaries

Water quality, habitat and living resource conservation are concerns applicable to all the Nation's estuaries. However, these problems are manifested differently in degree and scope among the various regions of the country. This summary provides a regional context to the national strategies developed in the plan.

NORTHEAST REGION

Characterization

The shoreline of the Northeast United States is interrupted by numerous estuaries that, although they can be discussed in terms of two distinct sub-regions, range broadly in size and other physical characteristics. These estuaries, extending from Maine to Cape Cod, were formed by glaciers that removed the soil cover, leaving a rocky shoreline and deeply carved steep-sided channels through which the estuaries run to the ocean. From Cape Cod to Maryland, the physical characteristics are the result of melting glaciers and rising sea level. Examples of these estuaries include the Narragansett and Delaware Bays, and the Long Island Sound. Many of the Northeast estuaries played essential roles in the development of this region as an early center of industry and human population. Estuarine waters served as routes for transportation and commerce, and provided the surrounding populations with recreational opportunities and abundant seafood.

With respect to living resources, the Northeast estuaries served as habitats to commercially and recreationally important fisheries. The extreme northern component of this region supports salmon, sea-run brook trout, shad and river herring as well as clams, scallops, and of course, lobster. From Cape Cod southward, important fisheries include striped bass, bluefish, flounder, menhaden, oysters, and clam.

Issues

Unfortunately, many of these estuaries also serve as receptacles for human and industrial wastes. The history of waste disposal in the Northeast is long. The legacy of the American industrial revolution is reflected in high metal concentrations in the sediments of many Northeast estuaries, and historical archives are replete with accounts of sewage contamination and typhus outbreaks caused by eating tainted shellfish. Many problems remain today because of outdated and overloaded sewage treatment facilities and inadequate treatment of industrial wastes. In addition, a vast majority of coastal Superfund sites are found in the Northeast. High levels of PCBs have been found in New

Bedford Harbor, Massachusetts, and in the resident lobsters and finfish. It has been designated a Superfund site, closing 28 square miles to fishing. Increased incidences of fish disease in Boston Harbor and Buzzards Bay have been linked to toxic contamination. Buzzards Bay has experienced shellfish bed closures along with PCB hotspots such as in the Acushnet Estuary. In Narragansett Bay, major concerns include the deterioration of the quohog fishery, beach closures from contaminated waters and the long term decline in finfish, oysters, scallops, and soft clams due to eutrophication. For these reasons, the major threat to estuarine quality in the Northeast generally is contamination, rather than processes such as physical destruction of estuarine habitats.

Key issues associated with the Northeast region include:

- Eutrophication
- Large phytoplankton blooms
- Toxic contamination
- Toxic transport and resuspension
- Microbial contamination (shellfish, for example, in the New York Bight)
- Municipal and industrial discharges
- Urban runoff
- Raw sewage discharges
- Combined sewer overflows

SOUTHEAST REGION

Characterization

The Southeastern estuarine region, beginning with the Chesapeake Bay and extending south to Florida, is characterized by three distinct types of shoreline formations. The first formation, typified by the Chesapeake Bay, is a coastal plain estuary formed from a drowned river bed. The estuaries of North Carolina and central Florida consist of lagoons landward of extensive barrier islands, while low lying, marshy shorelines characterize the coasts of South Carolina and Georgia. With the exception of Florida, the Southeastern coast is bordered by nearly 100 miles of plain and is characterized by tidal marshes, riverine swamps, and wetlands.

The region is well known for its abundance of fishery resources. In the Chesapeake, oysters and blue crabs are the key shellfish resources, while menhaden, bluefish, flounders, and anadromous species represent some of the most important finfish. Extending from North Carolina to Florida, popular shellfish include blue crabs, oysters, shrimp, and scallops. Finfish include menhaden, bluefish, anadromous species, croaker, mullet, seatrout, spot and flounder.

Issues

The attractive coastal islands off Georgia, the beautiful beaches of the Outer Banks, and intricate estuarine waterways combined with the pleasant climate of the Southeast has made this region a haven for primary residences and vacation homes. This very attraction has led to explosive development pressures from residential construction and relocation of industries. All population trends indicate the Southeast will continue to be faced with the enormous problem of balancing development pressures with coastal resource management. For example, the population along the shores of Maryland's portion of the Chesapeake Bay grew by 50% between 1950 and 1980, and Florida's coast is being settled at a rate of 3,000 - 4,000 people a week.

Non-point source runoff is a critical problem throughout the Southeast. Runoff from agricultural practices along the rivers of the Chesapeake and from the so-called "mega farms" of North Carolina dump loads of sediments, pesticides and nutrients into these estuaries. Runoff has led to often severe problems of eutrophication, low levels of dissolved oxygen, and changes in the fishery structures and in fishery habitat. Wetlands and marshes, so critical as nursery areas for larval and juvenile fish, are being lost to agricultural land conversions and construction at alarming rates.

With respect to the Chesapeake Bay, the major issues can be summarized as follows:

- Dramatic increases in anoxic bottom water from nutrient enrichment
- Drastic declines in submerged aquatic vegetation
- Increases in turbidity
- Shift from freshwater spawning fishes to saltwater fishes
- Increasing prevalences of fish diseases

For estuaries extending south of the Chesapeake Bay through Florida, the issues include:

- Large scale clearing on megafarms in North Carolina
- Massive development impacting wetlands
- Changes in hydrologic conditions and movement of nursery areas seaward
- Heavy nutrient loadings
- Periodic hypoxia/anoxic conditions
- Loss of seagrass beds especially in Tampa Bay
- Loss of shellfish from residential and urban development
- Physical loss of habitat from dredge and fill especially in Tampa Bay
- Contaminant hotspots in Baltimore Harbor, Elizabeth River and Savannah River

GULF OF MEXICO

Characterization

The Gulf of Mexico is characterized by low coastal plains, extensive saltwater marshes, and high levels of sediment deposition. The Gulf of Mexico also has the largest volume of wetlands in the country, constituting nearly 50% of the total coastal wetlands in the contiguous United States. Major depositional features include the Mississippi and Atchafalaya River Deltas, where large amounts of land-based sediments are deposited outside the river mouth in adjacent shallow coastal waters forming deltas. In other areas of the region, sediment transported and deposited by ocean currents has built offshore bars enclosing shallow, sometimes extensive bodies of water known as bar-built estuaries. Entrances to these estuaries tend to be narrow, so that exchanges with the sea are highly restricted. Estuaries of the northern Gulf also have the largest drainage areas in the Nation, receiving runoff from two-thirds of the contiguous United States, primarily through the Mississippi River watershed.

The Gulf is reknowned for its recreational and commercial fisheries, a resource upon which the local coastal economies have become increasingly dependent with the decline in the oil industry. The fish and shellfish of highest importance include menhaden, shrimp, oyster, blue crab, spotted seatrout, red drum, pompano, grouper, snapper, and flounder. The Gulf produces the largest volumes of menhaden and shrimp in the country. Total fisheries of this region represent 39 percent of the national total by weight, and 28 percent by value. An overwhelming majority of these fish are dependent on estuaries as critical habitats and food sources.

Issues

The coastal wetlands and adjacent inland wetlands of the Gulf are being lost at dramatic rates. It has been estimated that nearly 50 square miles of these valuable wetlands are being lost each year. Subsidence, channelization, pipelines, draining and levee construction along the Mississippi River all combine to further the demise of the wetlands and vital fisheries habitat in the region. The Gulf also suffers from extensive hypoxia, believed to be related to excessive nutrients flowing from the Mississippi River and into its delta. In 1985 alone, 8,000 square kilometers of the Louisiana shelf were hypoxic, a state which could severely affect the fisheries resources.

Important estuarine issues in this region can be summed up as follows:

- Loss of up to 25,000 acres/year of marsh habitat due to oil and gas canals, dredging, saline intrusion, levee construction, development, and subsidence
- Freshwater diversion leading to changes in salinity levels of estuaries and population levels of fisheries, especially in Texas
- Large quantities of industrial and municipal waste water discharges, petrochemicals, and pesticides, adversely affecting water quality to the detriment of public health
- Barataria Estuaries complex in Louisiana, a highly productive region for seafood, water commerce, mineral extraction, and recreation is becoming anoxic and polluted from expanded urban and agricultural development
- Eutrophication and oxygen depletion (especially as a result of a two-fold increase in nitrogen concentrations from agricultural runoff into the Mississippi River) may be connected to noxious blooms of "red tide" organisms and other noxious phytoplankton that has toxic affects on predators of seafood

SOUTHWEST REGION

Characterization

The Southwest region extends from the Mexican border to Mendocino, California. The coast is characterized by uniformly uplifted, resistant rock. The largest estuary in the region, the San Francisco Bay, formed when sections of the continent containing former river valleys sank below sea level because of active mountain building. With this geomorphology, estuaries are a relatively rare phenomenon along the entire west coastline.

Estuarine-related fisheries that have had long standing regional importance include salmon, steelhead trout, striped bass, and sturgeon. Marine mammals frequent the numerous open bays, and harbor seals and sea lions use San Francisco Bay as hauling grounds.

The beautiful estuaries and bays of the Southwest offer scenic vistas of rugged cliffs and headlands with windswept trees above a pounding surf. The beauty of San Francisco Bay and of the semi-tropical palm-fringed bays of Southern California, such as Mission Bay and San Diego Bay, are highly valued.

Issues

This region is not without environmental problems. The San Francisco Bay area, for example, has lost nearly all of its wetlands from diking and levee construction to provide land for massive agricultural development. Irrigated agriculture presents one of this estuary's greatest challenges - a redirection of 40-60% of the freshwater flow resulting in a decline in water quality, dramatic alteration of fisheries resources and the ecosystem.

In San Francisco Bay, the most critical issues are:

- Industrial and municipal discharges and agricultural drainage from the Sacramento and San Joaquin
- Loss of wetlands due to diking and filling
- Radical changes in fish populations due to large diversions in freshwater inflow
- Very high levels of toxic contaminants in shellfish
- Reduction of striped bass by 80%
- Accumulation of toxic contaminants in sediments
- Bioaccumulation and/or biomagnification of toxic contaminants in the marine food web
- Altered benthic species distribution, including kelp, from sewage and other offshore discharge
- Contamination by pathogens of coastal recreational areas due to sewage, vessel discharges, and runoff

NORTHWEST AND ALASKA

Characterization

This region encompasses Oregon, Washington, and Alaska, and is characterized by rugged, rocky outcroppings gradually shifting to low coastal flats and marshes in Washington. The Columbia River estuary and Puget Sound are the dominant estuarine systems of the Northwest region.

In Alaska, 34,000 miles of tidal shoreline represent approximately one-third of the total U.S. coastal shoreline. This large area is characterized by glacier-fed fjords, large open low relief estuaries, and hundreds of small bays and inlets. The delta regions along the Alaskan coast contain broad tidal and freshwater marshes. The Yukon River Delta is comparable in size and complexity to the Mississippi River Delta.

The fisheries are extremely important to the estuarine regions of the Northwest Region and Alaska. In the Northwest, key species include Pacific salmon, steelhead trout, shad, flounder, crabs, and clams. In addition to these species, important Alaskan fisheries include sablefish and scallops. Both regions support abundant populations of marine mammals including harbor porpoises, sea lions, and harbor seals. Both support habitat for the endangered humpback whale. Alaska also supports other mammals such as northern fur seals, sea otters, walruses, and beluga whales.

Issues

The problems in the Northwest differ largely in magnitude from those of Alaska. The Northwest area, as typified by Puget Sound, has become increasingly industrialized and suffers often from high concentrations of contaminants. These contaminants are introduced from a large number of point sources, including municipal treatment plants and industrial dischargers, such as oil refineries, pulp and paper mills, aluminum and steel processing plants, and chemical companies. Non-point sources from both urban areas and logging and farming practices, supply substantial volumes of metals and fecal coliforms. Shellfish bed closures due to bacterial contamination from runoff are rising even in rural embayments in the Sound. The entire eastern shore, where most of the population in the Puget Sound live, is uncertifiable for shellfish harvest as a result of sewage treatment plants, combined sewer overflows, and urban runoff. Major problems facing Northwest estuaries include:

- Toxic concentrations in sediments
- Toxic bioaccumulation in food webs
- Bacterial contamination of shellfish

- Liver tumors and fin erosion in bottom fish, such as English sole

In Alaska, population pressures have yet to exert comparable degradation of estuarine waters and habitat. It is the resource extraction industries such as fishing, oil and gas, logging, and mining, that will continue to be the focus of estuarine management concerns.

GREAT LAKES REGION

Characterization

The Great Lakes estuarine zone includes Lake Michigan and the United States shore of Lakes Superior, Huron, Erie, Ontario, and St. Clair. The Lakes occupy basins carved and deepened by Pleistocene glaciers from pre-glacial erosional basins and valleys of the St. Lawrence River system, and by erosion of sedimentary rocks along structural axes. No true estuaries occur in the Great Lakes, although their coastal shallows and marshes have qualities common to estuaries. More importantly, its coastal population rivals or exceeds in size any other region of the United States. Additionally, the retention of contaminants is far longer and more severe than ocean coastal areas because of the absence of flushing tides and indirect access to the vast sink provided by the oceans. The watershed of the lakes is largely a plain with hundreds of small streams. Many of the streams have glacial lakes and swamps in their courses. Large areas of the northern part of the watershed around Lakes Superior, Michigan, and Huron are forest, scrub, swamp, or bog. The southern parts are mainly cultivated or urban.

The Great Lakes are of great value to waterfowl and other fish and wildlife. The freshwater fishes include trout, bass, smelt, salmon, whitefish, northern pike, walleye, alewife, alke herring, yellow perch, and many others. Some of the native fishes, including longjaw cisco, deepwater cisco, blackfin cisco, and blue pike are endangered, and the lake sturgeon is close to extinction. The Lakes and their basin are migration stops for many species of migratory birds of the Central, Mississippi, and Atlantic flyways. Many varieties of ducks and Canadian geese use the Lakes. The marsh and upland, bay and river habitats also are important for upland game birds, and small and big game animals.

Issues

Areas of the southern regions of the Great Lakes are heavily populated and industrialized with the accompanying discharge and runoff problems. For example, combined sewer overflows and storm drains in many cities deliver untreated sewage or industrial wastes shunted away from Publicly-Owned Treatment works together with toxic urban runoff, directly into near coastal waters whenever it rains. Combined Sewer Overflows (CSO's) along the Rouge River in Detroit, Michigan produce a flow of industrial waste equal in volume to the Rouge, which enters the Detroit River and the Western end of Lake Erie during major storm events. Phosphorus loads from these CSO's constitute the third largest municipal load of nutrients to Lake Erie.

For the Great Lakes, atmospheric deposition is considered a significant source of degradation. Studies show that a significant portion of all loadings of metals to the Great Lakes are through atmospheric deposition, with trace organisms believed to follow the same path.

Other activities that create problems are agricultural runoff, land-fills, wetlands drain and fill, sediment dredging/disposition, and 61 hazardous waste sites that have the potential to contribute contaminants to Lake Ontario.

A summary of environmental quality problems includes:

- Loss of species habitat
- Microbial contamination of swimming waters
- Significant species changes observed in plankton, benthos, and finfish
- Fishing closures, public health advisories due to PCBs, pesticides and dioxins
- Annual anoxic episodes in Lake Erie and Green Bay
- Phytoplankton blooms in swimmable waters due to nutrient loadings
- Closure of commercial fisheries and sport fishing consumption advisories due to toxic contaminants